

Chapter 6

Primary Copper Processing

The domestic primary copper processing industry analyzed in this report consists of ten facilities that, as of September 1989, were active and reportedly generating one or more of the following mineral processing special wastes: slag (i.e., smelter, converter, and/or anode furnace slag), slag tailings, or calcium sulfate sludge from wastewater treatment. These ten primary processing facilities¹ conduct a variety of smelting and refining operations, including electrolytic refining.² The data included in this section are discussed in additional detail in a technical background document in the supporting public docket for this report.

6.1 Industry Overview

The majority of the copper consumed in the U.S. is used in the electrical industry. It is used for a wide range of wiring applications (from power transmission lines to printed circuit boards), in microwave and electrical tubes, motors and generators, and many other specialized applications where its high electrical and thermal conductivity can be employed. While copper has been replaced in some applications by aluminum (e.g., for overhead power lines) and fiber optics (e.g., in telecommunications), its durability, strength, and resistance to fatigue assure its continued use in the electrical industry. These latter three characteristics also make copper and copper alloys a valued material in construction and containment (e.g., pipes and tanks), and in other applications where endurance and resistance to corrosion are required.³

¹ In addition to the 10 primary facilities, several secondary processing facilities are operating; the operations conducted at these facilities, however, fall outside the definition of primary mineral processing and, thus, do not generate special mineral processing wastes.

² At least seven additional facilities concentrate copper at stand-alone electrowinning operations. These are, however, considered beneficiation operations, as long as they do not use as primary feedstock, materials that have undergone mineral processing operations, e.g., smelting and refining, (see 54 FR 36592, September 1, 1989). These facilities, their operations, and the wastes that they generate are not within the scope of this report.

³ Bureau of Mines, 1985. Mineral Facts and Problems, 1985 Ed., p. 206-7.

Exhibit 6-1
Primary Copper Processing Facilities

Owner	Location	Presence of Operation Type		
		Smelter and Converter	Anode Furnace	Electrolytic Refinery
ASARCO	Amarillo, TX	No	Yes	Yes
ASARCO	El Paso, TX	Yes	Yes	No
ASARCO	Hayden, AZ	Yes	Yes	No
RTZ/Kennecott	Garfield, UT	Yes	Yes	Yes
Copper Range	White Pine, MI	Yes	Yes	Yes
Cyprus	Claypool, AZ	Yes	Yes	Yes
Magma	San Manuel, AZ	Yes	Yes	Yes
Phelps Dodge	El Paso, TX	No	Yes	Yes
Phelps Dodge	Hurley, NM	Yes	Yes	No
Phelps Dodge	Playas, NM	Yes	Yes	No

The ten facilities in this study consist of four primary smelting and fire-refining facilities; four primary smelting, fire-refining, and electro-refining facilities; and two primary fire and electro-refining facilities, as shown in Exhibit 6-1. These facilities are located in five states, with nine of the ten facilities located in the Southwest. The dates of initial operation for these facilities range from 1912 to 1984; the average age is approximately 33 years. Most of the facilities have undergone modernization; the most recent in 1989. The total annual primary copper smelting production capacity is approximately 1.27 million metric tons per year of anode copper; the primary copper refining capacity is about 1.33 million metric tons per year of refined copper.

Primary production of copper in the U.S. has steadily increased throughout the late 1980s. Between 1986 and 1989, production from domestic and imported materials increased by 38 percent. Imports of refined copper for consumption have decreased by 40 percent (from 502,000 metric tons to 300,000 metric tons) since 1986, while exports have increased 833 percent (from 12,000 metric tons to 100,000 metric tons). Total apparent consumption has risen slightly from 2,136,000 metric tons in 1986 to 2,250,000 metric tons in 1989.⁴ Several companies have announced plans for improvements and expansions of existing facilities or opening new facilities in the early 1990s that would further increase the supply of copper coming from the U.S. ASARCO plans to expand its mining capacity and to employ a new flash smelting process at its El Paso, Texas facility.⁵ Kennecott has announced plans to increase production at its Utah

⁴ Janice Jolly and Daniel Edelstein, U.S. Bureau of Mines, Mineral Commodity Summaries, 1990 Ed., p. 52.

⁵ Tim O'Neil, "ASARCO: Plant Expansions and Modernizations Continue Amidst Company Restructuring," Mining Engineering, June 1989, p. 430.

copper operation by 32,000 metric tons per day.⁶ Finally, Mitsubishi has announced its intention to build a smelter at Texas City, Texas that would produce 150,000 metric tons of blister copper per year.⁷

The demand for copper is closely tied to the overall economy, and demand has remained relatively flat through the late 1980's. Future demand depends upon the health of the economy in the 1990s. Almost 40 percent of the 1988 U.S. consumption of copper went to the building and construction industries, while about 23 percent was used by the electrical and electronic industries. Industrial machinery and equipment, the power generation industry, and the transportation industry together consumed 38 percent of the copper produced in 1988.⁸ Clearly, the development of new infrastructure in the U.S. and abroad would increase the worldwide demand for copper, but consumption per unit of new gross product would be less than that in the past because substitutes for copper are often used in a number of industries. For example, new telephone infrastructure is being based upon fiber optic technology rather than copper to a significant degree.⁹ Continued re-opening of mothballed copper facilities, expansion of existing facilities, and development of new mines could lead to copper supplies increasing faster than demand.¹⁰

As seen in Exhibit 6-2, primary copper production operations include, in general, smelting, converting, fire refining in an anode furnace, and electrolytic refining. The products from each operation, respectively, are copper matte, blister copper, copper anodes, and refined copper. The term "copper smelting" is sometimes used to refer to the combined operations of smelting (in reverberatory, electric, or flash furnaces), converting,

⁶ "Kennecott Expanding Utah Copper," E&MJ, February 1990, p. 14.

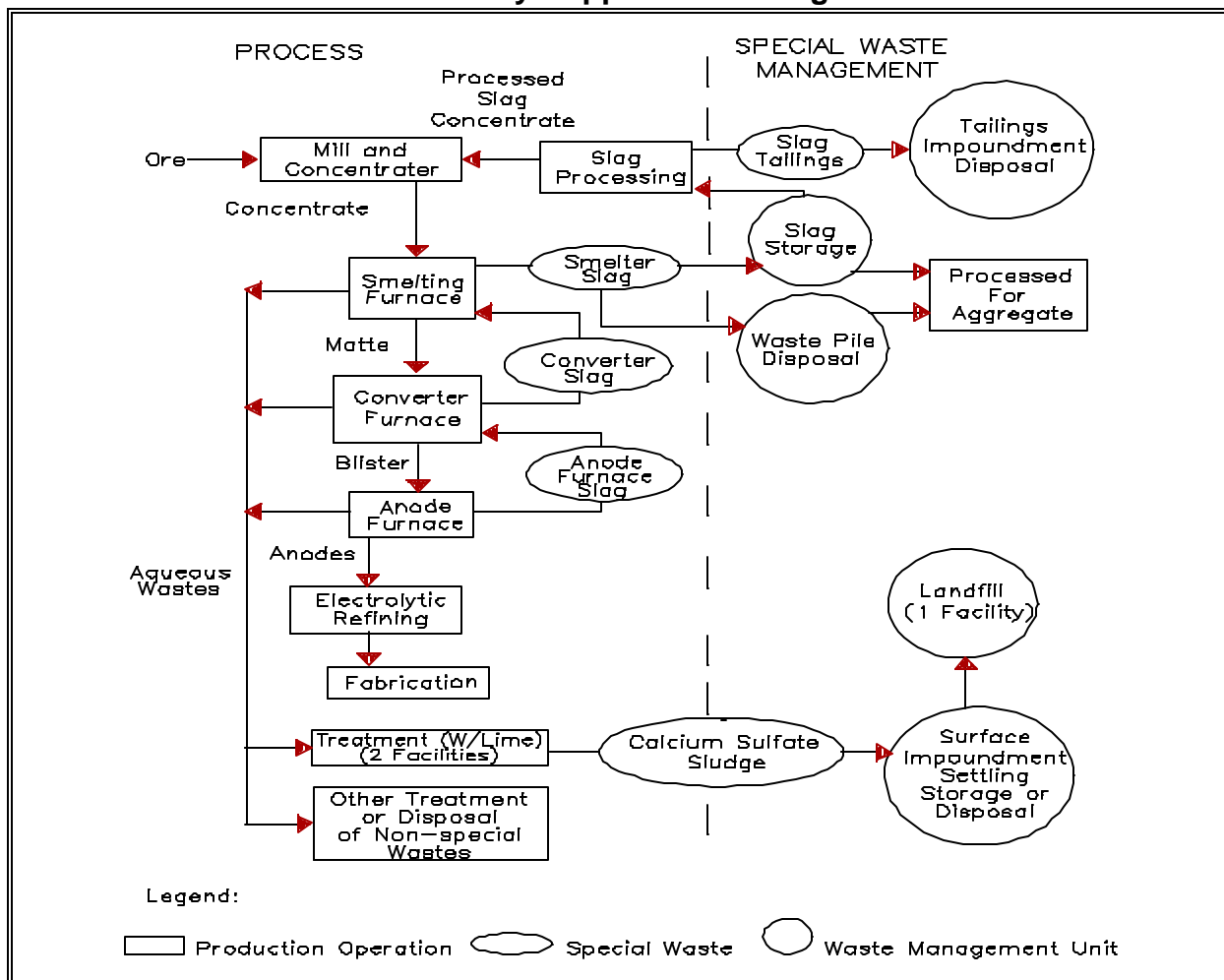
⁷ Simon D. Strauss, "Copper: 1989 Was a Good Year; 121st Annual Survey and Outlook," E&MJ, March 1990, p. 19.

⁸ "Copper's Future is as Clear as the Economy," E&MJ, January 1990, p. 15.

⁹ Ibid.

¹⁰ Ibid.

Exhibit 6-2
Primary Copper Processing



and often, when co-located, fire refining. For purposes of this report, smelting will refer to the initial step, in which the concentrate is first fused (i.e., heated to a point above the melting point of the mineral value).

Smelting involves the application of heat to a charge of copper ore concentrate, scrap, and flux, to fuse the ore and allow the separation of copper from iron and other impurities. Several types of smelting furnaces are in use in the

Exhibit 6-3 Summary of Furnace Types

Facility	Furnace Type
ASARCO, El Paso	Reverberatory (with pre-roast)
ASARCO, Hayden	Flash (Outokumpu)
RTZ/Kennecott	Noranda Reactor (Continuous Process)
Copper Range	Reverberatory
Cyprus	Electric
Magma	Flash (Outokumpu)
Phelps Dodge/Hurley	INCO Flash
Phelps Dodge/Playas	Electric and Flash (Outokumpu)

U.S., as shown in Exhibit 6-3. In all operations the furnaces produce two separate molten streams: copper-iron-sulfide matte and slag. The smelter slag, a special waste, is essentially a mixture of flux material, iron, and other impurities; the slag is typically hot dumped (i.e., poured into a storage/disposal pit or pile while still molten) and air cooled or cooled with water, or cooled with water (granulated) prior to dumping. The slags from some smelting furnaces are higher in copper content than the original ores taken from the mines. These slags, therefore, may be sent to a concentrator and the concentrate returned to the smelter. The waste portion of this slag processing operation is the second special waste, slag tailings from primary copper processing. Three facilities report reprocessing their slag, thereby generating slag tailings, a special waste.

The copper matte from the smelter furnace is typically routed hot to the converter furnace; some facilities have actually combined these operations. In either case, a high-silica flux and compressed air or oxygen are introduced to the molten matte. Most of the remaining iron combines with the silica to form converter slag, a special waste.¹¹ After removing the slag, additional air or oxygen is blown in to oxidize the sulfur and convert the copper sulfide to blister copper that contains about 99 percent copper; the sulfur is removed in the form of SO₂ gas, which reports to an acid plant where it is converted to high grade sulfuric acid. Depending on the efficiency of the acid plant, some amount of SO₂ is emitted to the atmosphere.

Oxygen and other impurities in blister copper must be removed before the copper can be fabricated or cast into anodes for electrolytic refining. Blister copper is fire refined in reverberatory or rotary furnaces known as anode furnaces; all ten facilities operate anode furnaces. When co-located, the furnace may receive the blister copper in molten form so remelting is unnecessary. Air is blown in to oxidize some impurities; flux may be added to remove others. A slag is generated during this anode furnace operation. This slag is also a component of the special waste.¹² The final step in fire refining is the reduction of the copper and oxygen removal using reformed natural gas of logs (potting) while it is still in the anode furnace, after which the molten copper may be cast into anodes for further electrolytic refining or wire-rod forms.

¹¹ Most if not all converter slag is recycled directly back to the smelter. When this occurs, this recycled material is not a solid waste (see 40 CFR Part 261).

¹² Most if not all anode furnace slag is recycled directly back to the converting furnace. When this occurs, this recycled material is not a solid waste (see 40 CFR Part 261).

Electrolytic refining, the final refining operation, does not directly generate a special waste and is not described in detail for this report. Along with the operations described above, however, electro-refining does produce various aqueous waste streams (e.g., process wastewater, bleed electrolyte) that must be treated and discharged, reused, or disposed in some manner. Many of the facilities use a wastewater treatment operation to treat these wastes. Two of the ten facilities, the Hayden, AZ and Garfield, UT facilities, use a treatment process employing lime as an additive to neutralize the wastewaters and precipitate dissolved metals. The solid residual from these treatment operations is a calcium sulfate sludge, which is the third special waste generated by the primary copper sector.

6.2 Waste Characteristics, Generation, and Current Management Practices

The three special mineral processing wastes generated by copper processing operations, slag, slag tailings, and calcium sulfate wastewater treatment sludge, are discussed separately below.

6.2.1 Slag from Primary Copper Processing

Slag from the smelting, converting, and anode furnaces is generated at eight of the ten facilities; the other two facilities (in Amarillo and El Paso) do not have smelting operations and produce only small quantities of anode furnace slag. Waste characteristic and generation rate data typically have not been reported for converter and anode furnace slag, as the slags are directly recycled. Because of the difference in generation rates and management of smelter slag versus converter and anode furnace slag (i.e., nearly all converter and anode furnace slag is recycled), smelter furnace slag is discussed separately from converter and anode slags.

Smelter Slag

Smelter slag is molten when tapped from the reactors and solidifies into a glassy, rock-hard mass upon cooling. When crushed, pieces of the copper slag may range in size from gravel to boulder, or even larger. The SWMPF Surveys describe the slag as a solid; typically gravel or cobble sized; and composed primarily of iron silicates, calcium oxide, and alumina (aluminum oxide), with small amounts of copper, lead, zinc, and other metals. The specific gravity of the slag is usually between 3.0 and 3.5.¹³

In 1988, the eight active smelters generated approximately 2.5 million metric tons of smelter slag. On an individual facility basis, the quantity generated at the six smelters that provided non-confidential data ranged from about 165,000 to nearly 500,000 metric tons. The smelter slag to copper anode production ratio is approximately 2.2 (i.e., 2.2 metric tons of smelter slag are generated for every ton of copper anode produced).

At all eight copper smelters, smelter slag is initially deposited on waste piles. In five cases, the waste piles are for temporary storage. At three of these five facilities, the slag is subsequently processed in a concentrator and the resulting concentrate is returned to the smelter. At another facility, the slag is moved to a pile at the edge of a tailings pond for disposal, and at the fifth, the slag is, in part, sold. At the three remaining facilities, the slag is disposed of in the waste piles and remains there indefinitely.

Three smelters process all their smelter slag either in their ore concentrator (San Manuel and White Pine) or, in the case of the Utah facility, in a stand-alone slag concentrator. The process streams resulting from this operation are slag tailings, discussed below as a separate special waste, and a copper concentrate which is sent to the smelter as feedstock. Information on the stockpiles of smelter slag at two of these facilities was not reported. At the White Pine facility, the slag is dumped in a slag pile covering 24 hectares (60 acres) and 3 meters (10 feet) in height, from which the slag is periodically removed and sent to the concentrator. This slag dump has accumulated as of 1988, 1.36 million metric

¹³ Collins, R.J. and R.H. Miller, Availability of Mining Wastes and Their Potential for Use as Highway Material - Volume I: Classification and Technical and Environmental Analysis, FHWA-RD-76-106, prepared for Federal Highway Administration, May 1976, p. 113.

tons of slag; having been used as a disposal unit for some years. In 1988, however, more slag was removed from the dump for slag processing (212,000 metric tons) than was generated from the smelter (165,000 metric tons).

The temporary slag pile at the ASARCO/El Paso facility which, in 1988 sold its slag, is much smaller in comparison to the disposal piles, with a basal area of 0.9 hectares (2.1 acres) and 6 meters (20 feet) high; 450,000 metric tons of slag had accumulated as of 1988.

Four facilities (Hayden, AZ, Claypool, AZ, Playas, NM and Hurley, NM) dispose of all or part of the slag in on-site slag piles or slag dumps. The Claypool facility disposes of its slag in a pile at the edge of a tailings pond. As of 1988, the basal area of these slag piles ranged from 7 to 26 hectares (17 to 64 acres), and the height from 6 to 45 meters (20 to 150 feet.) The amount of slag accumulated in any one of these slag piles ranges from 2.7 to 20.9 million metric tons.

Using available data on the composition of copper smelter slag, EPA evaluated whether the slag exhibits any of the four characteristics of hazardous waste: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Based on available information and professional judgment, EPA does not believe the slag is corrosive, reactive, or ignitable, but some slag may exhibit the characteristic of EP toxicity. EP leach test concentrations of all eight inorganic constituents with EP toxicity regulatory levels are available for copper smelter slag from seven of the ten facilities of interest. Of these constituents, cadmium and lead concentrations, in one sample from just one facility (Phelps Dodge at Playas, NM), were found to exceed the EP regulatory levels. Cadmium was present at concentrations in excess of 8.5 times the regulatory level, in one of 70 samples. Likewise, lead concentrations exceeded the EP regulatory level in one of 68 samples, by a factor of roughly three. Because the slag samples that failed the EP toxicity test were not analyzed using the SPLP leach test, it is not clear if cadmium and lead concentrations would have exceeded the EP toxicity levels if the SPLP test had been used.

Converter and Anode Furnace Slag

Approximately 380,000 metric tons of converter and anode slag are generated annually, ranging from nearly 29,000 to just over 244,000 metric tons for the six non-confidential facilities with smelting operations; the one non-confidential electrolytic refinery generated only 1,200 metric tons of anode furnace slag.

The primary management practice for both the converter and anode furnace slag is recycling. The eight facilities that have smelters and, therefore, converter operations, all recycle their converter slag back to the smelter furnace and their anode furnace slag back to their converter. ASARCO/Amarillo and Phelps Dodge/El Paso each operate a stand-alone refinery with an anode furnace; both ship their anode furnace slag back to one of their two company-owned smelters for resmelting. Temporary waste piles are used to store the slag before it is shipped off-site.

6.2.2 Slag Tailings from Primary Copper Processing

Slag tailings from primary copper processing is a solid material, typically composed of particles smaller than sand, that is settled from a slurry. Only three facilities, those in Michigan, Utah, and San Manuel, AZ, presently send their smelter slags to a concentrator and thereby generate slag tailings. At the Michigan and San Manuel, AZ facilities, the same concentrator is used for both ore and slag, so the slag tailings and ore tailings are co-generated. The Utah facility has separate concentrators for the ore and slag, but the slag tailings and ore tailings are mixed prior to disposal. The primary constituents in slag tailings reportedly are silicon, iron, magnesium, sodium; smaller amounts of copper, lead, and zinc; and other trace elements.

Non-confidential waste generation rate data were provided to EPA by all three facilities generating slag tailings. The aggregate annual industry-wide generation of slag tailings by the three plants was approximately 1.5 million metric tons in 1988, yielding a facility average of nearly 504,000 metric tons per year. Individual facility generation rates ranged from 206,000 to nearly 969,000 metric tons. The average waste-to-product tonnage ratio (i.e., slag tailings to copper anode) for the three facilities was 1.4 in 1988.

Slag tailings are co-managed in on-site tailings ponds with tailings from ore beneficiation at all three facilities. One facility, located in Michigan, has five tailings ponds on-site, while the other two facilities (in Utah and Arizona) each have a single tailings pond. These ponds cover anywhere from 142 to 2,270 hectares (352 to 5,600 acres) each. Industry-

wide, these ponds cover a total area of 4,400 hectares, yielding a facility-specific average of approximately 600 hectares. On average, the ponds are roughly 46 meters (150 feet) deep (depth may range from 16 to 61 meters).

The combined amount of slag tailings accumulated at all seven ponds, as of 1988, is approximately 12.6 million metric tons. The average quantity of slag tailings accumulated in each pond is roughly 1.8 million metric tons, although it could range from 241,000 to 3.4 million metric tons. At all three facilities, slag tailings constitute a relatively minor portion of the total tailings (slag plus ore/mill tailings) held in each of the tailings ponds. Slag tailings at the Michigan plant range from 0.2 to 3.5 percent of the total tailings in the five ponds. At the other two facilities, slag tailings are 0.3 and 2.6 percent of the total tailings managed in the ponds.

Data available to EPA from site sampling visits and responses to a RCRA §3007 request, as well as professional judgment, indicate that slag tailings do not exhibit any of the characteristics of hazardous waste (i.e., ignitability, reactivity, corrosivity, or EP toxicity) at any of the facilities that generate the waste. These data identify the concentrations of all eight inorganic EP constituents in slag tailings samples from two of the three facilities (Garfield and San Manuel) that generate this waste. Using the EP leach test, all eight constituents were measured in concentrations that were at least two orders of magnitude below the EP-toxicity regulatory levels -- that is, below primary drinking water standards.

6.2.3 Calcium Sulfate Wastewater Treatment Plant Sludge From Primary Copper Processing

Calcium sulfate sludge is generated only by the facilities in Hayden, AZ, and Garfield, Utah from lime treatment of wastewaters (e.g., acid plant blowdown). At the Utah facility, the sludge reportedly consists primarily of calcium sulfate (70 percent), with between 0.1 and 0.5 percent copper, zinc, and lead. Additional metals are present in trace amounts.¹⁴ The total annual generation of calcium sulfate sludge is estimated to be approximately 140,000 metric tons per year and the average waste-to-product (smelter output) ratio is 0.42.¹⁵

The waste management practice used at both facilities is accumulation of the sludge solids in an on-site impoundment. At the Utah facility, two on-site surface impoundments are used for sludge storage. Both impoundments have a surface area of about 2.2 hectares (5.5 acres); one impoundment is 2.3 meters (7 feet) deep and the other is 3 meters deep. One impoundment is used to accumulate sludge, while sludge previously accumulated in the second ("inactive") impoundment is allowed to dry prior to dredging. The air-dried sludge in the inactive impoundment is dredged and stabilized, and then disposed in a landfill that is located in a designated area within the on-site tailings impoundment.

The Hayden, AZ facility also accumulates its calcium sulfate slurry in an on-site surface impoundment. In 1988, approximately three percent of the sludge was dredged from the impoundment and recycled to the flash furnace; the remainder was left to accumulate in the impoundment, which has an area of 3.35 hectares (8 acres) and is 3.2 meters (10 feet) deep. The impoundment has an asphalt/rubber liner and run-on/run-off controls; no leachate or wind dispersal controls are used.

Using available data on the composition of calcium sulfate wastewater treatment plant sludge, EPA evaluated whether the waste exhibits any of the four hazardous waste characteristics: corrosivity, reactivity, ignitability, and extraction procedure (EP) toxicity. Based on available information and professional judgment, EPA does not believe that this waste is corrosive, reactive, or ignitable, but it does exhibit the characteristic of EP toxicity. EP leach test concentrations of all eight inorganic constituents with EP toxicity regulatory levels are available for one of the two facilities of interest (Garfield). Of these constituents, arsenic, cadmium, and selenium concentrations were found to exceed their respective regulatory levels. Concentrations of arsenic and selenium exceeded EP-toxicity regulatory levels

¹⁴ According to the EPA waste sampling and analysis data, the sludge from primary copper processing contains copper (0.154%), lead (0.144%), arsenic (0.117%), iron (0.0351%), zinc (0.0232%), aluminum (0.0157%), and smaller amounts of antimony, barium, beryllium, cadmium, cobalt, mercury, manganese, molybdenum, nickel, selenium, silver, thallium, and vanadium.

¹⁵ One of the two respondents to EPA's 1988 survey indicated that the quantity of calcium sulfate sludge generated was confidential. As a result, the estimated average quantity presented here is based on alternative data sources as discussed in the technical background document.

in all of the seven samples analyzed, by factors as high as 140 and 14, respectively. Cadmium concentrations exceeded the EP-toxicity threshold in six of the seven samples, by as much as four times the regulatory level. On the other hand, SPLP leach test concentrations of metals with EP-toxicity limits were below the EP-toxicity regulatory levels for all of the samples analyzed.

6.3 Potential and Documented Danger to Human Health and the Environment

In this section, EPA discusses two of the study factors required by Section 8002(p) of RCRA for wastes generated in the copper processing sector: (1) potential risk to human health and the environment associated with the management of copper slag, copper slag tailings, and calcium sulfate sludge generated at copper processing plants; and (2) documented cases in which danger to human health and/or the environment has been proven. Overall conclusions about the hazards associated with each of the three wastes are based on the Agency's evaluation of these two factors.

6.3.1 Risks Associated With Copper Slag

Any potential danger to human health and the environment from copper slag is a function primarily of the composition of the slag, the management practices that are used, and the environmental settings of the facilities where the slag is generated and managed. These factors are discussed separately below, followed by EPA's risk modeling results for this waste.

Constituents of Concern

EPA identified chemical constituents in copper slag that may present a hazard by collecting data on the composition of slag, and evaluating the intrinsic hazard of chemical constituents present in the slag.

Data on Copper Slag Composition

EPA's characterization of copper slag and its leachate is based on data from three sources: (1) a 1989 sampling and analysis effort by EPA's Office of Solid Waste (OSW); (2) industry responses to a RCRA §3007 request in 1989; and (3) sampling and analysis conducted by EPA's Office of Research and Development (ORD) in 1984. These data provide information on the concentrations of 21 metals and a number of inorganic constituents (i.e., phosphorus, fluoride, sulfate, and nitrate) in total and/or leach test analyses, and represent samples from all 10 facilities that generate copper slag.

Concentrations in total (solid) samples of the copper slag are consistent for most constituents across all data sources and facilities. Arsenic and nickel concentrations, however, varied over three orders of magnitude across the facilities.

Concentrations of constituents from leach test analyses of the copper slag generally are consistent across the data sources, types of leach tests (i.e., EP, SPLP, and TCLP), and facilities. In the EP analyses, however, chromium, zinc, and lead concentrations varied over approximately three orders of magnitude across the facilities.

Process for Identifying Constituents of Concern

As discussed in detail in Section 2.2.2, the Agency evaluated the data summarized above to determine if copper slag or slag leachate contain any chemical constituents that could pose an intrinsic hazard, and to narrow the focus of the risk assessment. The Agency performed this evaluation by first comparing the constituent concentrations to screening criteria and then by evaluating the environmental persistence and mobility of constituents present in concentrations above the criteria. These screening criteria were developed using assumed scenarios that are likely to overestimate the extent to which the slag constituents are released to the environment and migrate to possible exposure points. As a result, this process identifies and eliminates from further consideration those constituents that clearly do not pose a risk.

The Agency used three categories of screening criteria that reflect the potential for hazards to human health, aquatic ecosystems, and water resources (see Exhibit 2-3). Given the conservative (i.e., protective) nature of these screening criteria, contaminant concentrations in excess of the criteria should not, in isolation, be interpreted as proof of hazard. Instead, exceedances of the criteria indicate the need to evaluate the potential hazards of the waste in greater detail.

Identified Constituents of Concern

Exhibits 6-4 and 6-5 present the results of the comparisons for copper slag (total) analyses and leach test

Exhibit 6-5 Potential Constituents of Concern in Copper Slag Leachate^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Lead	46 / 69	Human Health Resource Damage Aquatic Ecological	15 / 69 37 / 69 12 / 69	6 / 10 7 / 10 6 / 10
Copper	14 / 14	Human Health Resource Damage Aquatic Ecological	2 / 14 2 / 14 13 / 14	2 / 8 2 / 8 8 / 8
Arsenic	24 / 70	Human Health* Resource Damage	24 / 70 2 / 70	7 / 10 1 / 10
Molybdenum ^(c)	1 / 2	Resource Damage	1 / 2	1 / 2
Cadmium	46 / 71	Human Health Resource Damage Aquatic Ecological	6 / 71 8 / 71 7 / 71	5 / 10 5 / 10 5 / 10
Mercury	7 / 69	Aquatic Ecological	5 / 69	2 / 9
Potential Constituents of Concern in Copper Slag Solids^(a)				
Iron	12 / 14	Resource Damage	2 / 14	2 / 8
Barium	28 / 70	Human Health Resource Damage	1 / 70 1 / 70	1 / 10 1 / 10
Chromium	20 / 71	Resource Damage Aquatic Ecological	1 / 71 1 / 71	1 / 10 1 / 10
Manganese	5 / 14	Resource Damage	26 / 42	5 / 8
Copper	44 / 45	Ingestion	28 / 45	5 / 9
Zinc	14 / 14	Aquatic Ecological	1 / 14	1 / 9
Lead	41 / 43	Ingestion	31 / 43	6 / 9
Chromium	6 / 15	Inhalation*	3 / 15	3 / 8
Antimony	26 / 43	Ingestion	9 / 43	2 / 9
Silver	37 / 50	Ingestion	25 / 50	2 / 9
Nickel	21 / 27	Inhalation*	2 / 27	1 / 9

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample. Unless otherwise noted, the constituent concentrations used for this analysis are based on EP leach test results.
- (b) Human health screening criteria are based on exposure via incidental ingestion and inhalation. Human health effects include cancer risk and noncancer health effects. Screening criteria noted with an "*" are based on a 1×10^{-5} lifetime cancer risk; others are based on noncancer effects.
- (c) Data for this constituent are from SPLP leach test results.

analyses, respectively, to the risk screening criteria. These exhibits list all constituents for which sample concentrations exceed a screening criterion.

Of the 24 constituents analyzed in copper slag solids, arsenic, copper, lead, chromium, antimony, silver, and nickel are present at concentrations exceeding the screening criteria (see Exhibit 6-4). Among these constituents, arsenic, copper, and lead appear to pose the greatest potential threat because they were detected in most (73 to 98 percent) of the samples analyzed, their concentrations in most (61 to 73 percent) analyses exceed screening criteria, and their concentrations in samples from at least 5 of the 9 facilities exceed the screening criteria. In addition, only arsenic, copper, and lead exceeded the screening criteria by more than a factor of ten. All of these constituents are persistent in the environment (i.e., they do not degrade).

These exceedances indicate the potential for the following types of impacts under the following conditions:

- Arsenic, copper, lead, and to a lesser extent, antimony and silver concentrations exceed the ingestion criteria. This indicates that, if the slag (or soil contaminated with the slag) is incidentally ingested on a routine basis then constituents may cause adverse health effects. The concentration of arsenic in the slag would pose a lifetime cancer risk of greater than 1×10^{-5} if incidentally ingested.
- Arsenic, chromium, and nickel concentrations exceed the health-based screening criteria for inhalation. This indicates that these constituents could pose a cancer risk greater than 1×10^{-5} if slag dust were blown into the air and inhaled in a concentration that equals the National Ambient Air Quality Standard for particulate matter.

Based on a comparison of leach test concentrations of the 24 constituents to the surface and ground-water pathway screening criteria (see Exhibit 6-5), 11 contaminants were detected in concentrations above the criteria. Lead, copper, arsenic, molybdenum, and cadmium are present in concentrations that exceed at least one screening criterion in samples from at least 50 percent of all facilities at which they were analyzed. The other six constituents are present in concentrations that exceed the screening criteria in samples from no more than two of eight facilities. Maximum lead, copper, and arsenic concentrations exceed the screening criteria by more than a factor of 100, and maximum concentrations of molybdenum, cadmium, and mercury exceed the criteria by more than a factor of 10. The other constituents exceed the criteria by less than a factor of 10. As discussed in Section 6.2.1, the only constituents that were measured in concentrations that exceed the EP toxicity regulatory levels were cadmium (in 1 of 70 samples) and lead (in 1 of 68 samples).

- Concentrations of lead, copper, arsenic, cadmium, and barium in copper slag leachate exceed health risk (drinking water) screening criteria. This indicates that, if slag leachate were released and diluted by only a factor of 10 during migration to a drinking water exposure point, long-term ingestion could cause adverse health effects due to the presence of these constituents. The concentration of arsenic in diluted slag leachate could pose a cancer risk of greater than 1×10^{-5} .
- Lead, copper, cadmium, mercury, chromium, and zinc in the slag leachate may present a threat to aquatic organisms if it migrates (with a 100-fold dilution) to surface waters.
- Lead, copper, arsenic, molybdenum, cadmium, iron, barium, chromium, and manganese in the slag leachate, if released and diluted by a factor of 10 or less, could restrict the potential future uses of affected ground- and surface water resources.

These exceedances, by themselves, do not indicate that the slag poses a significant risk, but rather indicate that the slag may present a hazard under a very conservative, hypothetical set of release, transport, and exposure conditions. To determine the potential for the slag to cause significant impacts, EPA proceeded to the next step of the risk assessment to analyze the actual conditions that exist at the facilities that generate and manage the slag.

Release, Transport, and Exposure Potential

This analysis considers the baseline hazards of copper slag as it was generated and managed at the 10 plants of concern in 1988. For this analysis, the Agency did not assess the hazards associated with variations in waste management practices or potentially exposed populations in the future because of a lack of information adequate to predict future conditions. In addition, the following analysis does not consider the risks of off-site disposal or use of the slag because the slag is disposed of only on-site. Although one facility does sell its slag for off-site use and there is a potential for wider use of the slag in the future, insufficient information about the conditions of off-site use is available to support a detailed assessment of risks. Alternative slag management practices are discussed, however, in Section 6.5.

Ground-Water Release, Transport, and Exposure Potential

EPA and industry test data discussed above indicate that several constituents are capable of leaching from copper slag in concentrations that exceed the screening criteria. However, considering the existing slag management practices and neutral pH of the leachate, the only slag contaminants that are expected to be mobile in ground water if released are arsenic, molybdenum, cadmium, and to a lesser extent, barium and chromium. Exhibit 6-6 summarizes the key factors at each copper facility that affect the potential for these constituents to be released into ground water and cause impacts through that pathway.

Exhibit 6-6

Summary of Release, Transport, and Exposure Potential for Copper Slag

Facility	Release, Transport, and Exposure Potential for Copper Slag	Proximity to Sensitive Environments
AMARILLO*	<p>Ground water: Although moderate recharge (10 cm/year) and permeable subsurface (80 percent sand), useable aquifer very deep (73m below facility) and thus somewhat protected.</p> <p>Surface water: No permanent water body within 1.6 km; a nearby playa lake could be contaminated by shallow ground-water discharge, but water is present only intermittently; when present, water may be used for livestock watering.</p> <p>Air: Small number of wet days (66 days/year) and high wind speeds (6.6 m/s) could lead to airborne dust and inhalation exposures at closest residence 760 meters from the facility; sparse population (5 people) within 1.6 km.</p>	Not located in or near any sensitive environments
ASARCO/EL PASO	<p>Ground water: Temporary slag management area has no engineered ground-water controls and ground water is shallow (3-6 meters), but releases are limited by low precipitation (20 cm/year) and very low net recharge (0.5 cm/year); no drinking water wells within 1.6 km of the facility.</p> <p>Surface water: Overland releases to the Rio Grande River have been documented (damage case); high potential for episodic overland releases to nearby river (76 meters) because of steep topographic slope (6-12%) and the facility is located in a 100-year floodplain; river has large flow (520 mgd) that yields significant dilution; drinking water intake 4 km downstream (500,000 people served).</p> <p>Air: Releases not controlled by dust suppression; small number of wet days (41 days/year) that may suppress dust and wind speeds up to 5.1 m/s could lead to airborne dust and inhalation exposures at closest residence 90 meters from the facility; population within 1.6 km is 500.</p>	Located in a 100-year floodplain
HAYDEN	<p>Ground water: Waste pile is not lined, annual precipitation is moderate (50 cm/year) and subsurface is slightly permeable; very low net recharge, i.e., 1.3 cm/year, creates low potential for releases to shallow ground water located roughly 6 m below the land surface; ground water does not appear to be used for any purpose.</p> <p>Surface water: Routine overland releases to nearby Gila River (located 80 meters from the facility) limited by stormwater runoff/runoff controls and the gentle (0-2%) topographic slope in the area; low potential for releases to surface water via seepage to ground water; no consumptive uses of the river within 24 km; moderate flow of the river (170 mgd) allows moderate dilution, and therefore, possible ecological risks.</p> <p>Air: Releases not controlled by dust suppression; small number of wet days (47 days/year), large exposed area of the pile, and wind speeds up to 4.8 m/s could lead to airborne dust and inhalation exposures at closest residence 90 meters from the facility; population within 1.6 km is 2,200.</p>	Not located in or near any sensitive environments

* No information is available on the slag management units at these sites. The information presented here is based only on the environmental setting of the facility.

Exhibit 6-6 (continued)
Summary of Release, Transport, and Exposure Potential for Copper Slag

Facility	Release, Transport, and Exposure Potential for Copper Slag	Proximity to Sensitive Environments
WHITE PINE	<p>Groundwater: High potential for releases to ground water due to absence of engineered controls, moderately shallow depth to aquifer (6-12 meters), high precipitation (73 cm/year), and relatively high net recharge (18 cm/year); no drinking water wells within 1.6 km of the facility.</p> <p>Surface water: Large annual precipitation and moderate topographic slope (up to 6%) together create potential for surface erosion and overland runoff to a stream located 120 m from facility; however, slag pile equipped with stormwater run-on/run-off control surface water monitoring has indicated exceedances of drinking water and ambient water quality standards; episodic overland releases due to sudden snow-melt (maximum snow accumulation is 94 cm/storm) and releases to surface water via seepage to ground water could occur; stream has low dilution capacity (42 mgd); potential drinking water exposures could occur from a water supply intake 5 km downstream.</p> <p>Air: Dust suppression is not practiced but moderate number of wet days (116 days/year) could control airborne dust; wind speeds up to 4.7 m/s have the potential for producing airborne dust that could lead to potential airborne exposures at closest resident 730 meters from the facility; population within 1.6 km is 1,200.</p>	Located in a Fault Zone and close to a National Forest
GARFIELD*	<p>Groundwater: Releases to useable ground water limited by low precipitation (40 cm/year) and net recharge (0.7 cm/year) and large depth to the aquifer (90 meters) that is overlain with clay; however, monitoring shows ground water contamination has occurred; contamination has not been attributed to copper slag; no drinking water wells within 1.6 km.</p> <p>Surface water: Episodic overland releases to the Great Salt Lake (300 m from facility) could occur due to a flood-event or sudden snow-melt (maximum snow accumulation is 102 cm); routine overland releases and releases via seepage to ground water are of lesser concern; low potential for exposure because the lake is not used for drinking water.</p> <p>Air: Releases not controlled by dust suppression; small number of wet days (89 days/year) and wind speeds up to 4.9 m/s could lead to airborne dust; significant potential for inhalation exposure because population within 1.6 km is 10,000.</p>	Located in a 100-year floodplain and in a wetland

* No information is available on the slag management units at these sites. The information presented here is based only on the environmental setting of the facility.

Exhibit 6-6 (continued)
Summary of Release, Transport, and Exposure Potential for Copper Slag

Facility	Release, Transport, and Exposure Potential for Copper Slag	Proximity to Sensitive Environments
SAN MANUEL*	<p>Ground water: No information is available on the ground-water controls at the temporary cooling pits for the slag that is recycled; releases to uppermost useable aquifer are significantly limited by large depth to the useable aquifer (140 meters), moderate precipitation and zero net recharge, and presence of an intervening layer of impervious lake-bed deposits; closest drinking water well is located 150 m from the facility.</p> <p>Surface water: Some potential for surface erosion because moderate precipitation (50 cm/year), moderate topographic slope (up to 6%) of the area, and moderate distance to nearby San Pedro River (790 meters); very low dilution capacity (0.08 mgd) of the stream could lead to ecological risks; no public water supply intake within 24 km of the facility, but there is an intake for livestock watering 1.2 km downstream.</p> <p>Air: No information is available on dust suppression controls at the slag cooling pits; airborne releases could be possible due to small number of wet days (47 days/year) and average wind speeds up to 4.8 m/s; potential inhalation exposures could occur at closest residence 330 meters from the facility; population within 1.6 km is 5,000.</p>	Not located in, or near, any sensitive environments
PHELPS DODGE/ EL PASO	<p>Ground water: Low potential for releases to ground water because of low precipitation (20 cm/year), very low net recharge (0.5 cm/year), large depth to aquifer (76 m), and presence of an asphalt liner beneath the temporary slag pile; no drinking water wells within 1.6 km downgradient of the facility.</p> <p>Surface water: Overland releases are limited by stormwater runoff controls and low precipitation; given low potential for ground-water contamination, very unlikely that contaminants could migrate via ground water into Gila River located 550 m away; contaminants pose low risks to aquatic receptors because the river has a large dilution capacity (515 mgd); no consumptive uses of the river within 24 km.</p> <p>Air: Releases not controlled by dust suppression; small number of wet days (41 days/year) and average wind speeds up to 5.1 m/s could lead to airborne dust and inhalation exposures at closest residence 30 meters from the facility; significant exposures could occur because population within 1.6 km is 40,000.</p>	Located in a Fault Zone
HURLEY	<p>Ground water: Ground water monitoring has indicated contamination, but the contamination has not been attributed to copper slag; although no engineered ground-water controls and permeable subsurface, the low net recharge (5 cm/year) and large depth to ground water (30 m) help to limit releases from copper slag; potential exposures could occur at drinking water well <100 meters downgradient of the facility boundary.</p> <p>Surface water: There are no surface water bodies within 24 km of the facility.</p> <p>Air: Releases not limited by dust suppression controls; small number of wet days (50 days/year) and average wind speeds up to 4.3 m/s could lead to airborne dust and inhalation exposures at closest residence 6 meters from the facility; population within 1.6 km is 5,500.</p>	Located in a 100-year floodplain, Fault and Karst Zones

* No information is available on the slag management units at these sites. The information presented here is based only on the environmental setting of the facility.

Exhibit 6-6 (continued)
Summary of Release, Transport, and Exposure Potential for Copper Slag

Facility	Release, Transport, and Exposure Potential for Copper Slag	Proximity to Sensitive Environments
PLAYAS	<p>Groundwater: Potential for release to shallow aquifer (4 m) is limited by low precipitation (26 cm/year) and zero net recharge; potential for exposure is minimal because closest drinking water well is more than 5 km downgradient.</p> <p>Surface water: Low potential for surface erosion because of low precipitation and gentle topographic slope of the area; seepage of contaminants to ground water that may discharge into the nearby (480 m) Playas Lake is also limited; lake water is not used for human consumption but is used for livestock watering.</p> <p>Air: Releases not limited by dust suppression controls; small number of wet days (40 days/year) and average wind speeds up to 5.3 m/s could lead to airborne dust; however, potential for inhalation exposures is relatively low because the closest residence is approximately 3.7 km from the facility, and there is no population within 1.6 km.</p>	Located in a Fault Zone, and within 9 miles of an endangered species habitat
CLAYPOOL	<p>Groundwater: Releases are not limited by any engineered ground-water controls; standing liquid over some part of the slag in the tailings pond provides a leaching medium; contaminants could leach into the permeable subsurface (high percentage of sand); aquifer is very deep (91 to 116 m); potential drinking water exposures could occur at municipal well 1.2 km downgradient (approximately 9500 people rely on this well).</p> <p>Surface water: The closest surface water (Salt River) is 24 km away.</p> <p>Air: Release not limited by dust suppression controls; small number of wet days (43 days/year) that could suppress dust and average wind speeds up to 3.4 m/s could lead to airborne dust and inhalation exposure at closest residence 60 meters from the facility; population within 1.6 km is 1,000.</p>	Located in a Fault Zone and close to a National Forest

No information is available on the slag management units at these sites. The information presented here is based only on the environmental setting of the facility.

Seven of the 10 facilities in this sector provided information on their copper slag management units and it appears that, industry-wide, engineered ground-water controls are very limited. In addition to engineered controls, the potential for contaminant releases to ground water and subsequent transport to exposure points is determined by a number of site-specific factors, such as depth to ground water, precipitation and net recharge, the presence of intervening confining layers/aquifers, and the distance to downgradient drinking water wells. Considering these factors, the potential for contaminants to migrate into ground water is high at two facilities (White Pine and Hurley) and the potential for exposure to this contamination appears high at one facility (Hurley). The potential for contaminant migration and exposure at the other facilities is low to moderate, as summarized below.

- At the ASARCO/El Paso, Playas, and Phelps Dodge/El Paso facilities, the potential for slag contaminants to infiltrate into the underlying aquifers is significantly limited by low precipitation (20 to 26 cm/year) and very low net recharge (0 to 0.5 cm/year). Furthermore, the slag pile at the Phelps Dodge/El Paso facility is lined with asphalt, which provides limited control, and the ground water at this site is very deep (76 meters). Even if ground-water releases were to occur at these facilities, the potential for current drinking water exposures is low because there are no known downgradient drinking water wells within 1.6 km (1 mile) of the facilities.
- Ground-water releases from the slag piles at Claypool and Hayden due to infiltrating rainwater are also limited by low net recharge (i.e., 1 to 2.5 cm/year) at these facilities. At the Claypool facility, because a part of the slag is submerged in liquids, there may be a greater potential for contaminants to leach into the subsurface, but the useable aquifer at this facility is very deep (at least 91 meters below the land surface) and thus somewhat protected. If there is a release, current drinking water exposures are possible at Claypool because a large number of people (9,500) rely on a municipal drinking water well 1.2 km downgradient of the facility. According to the Hayden facility's survey response, ground water is not used for any purpose within 1.6 km (a mile) of the facility.
- The potential for releases from the slag piles to ground water is relatively high at White Pine and Hurley. At the White Pine facility, high rainfall (73 cm/year) and high net recharge (18 cm/year) indicate that, despite the clay layer beneath the waste pile, some amount of seepage from the pile could migrate to the moderately shallow aquifer (6 to 12 meters deep). Current drinking water exposures are unlikely at this facility because, to the best of EPA's knowledge, there are currently no downgradient wells within mile. Releases to ground water could, nevertheless, restrict the potential future uses of the aquifer. Although net recharge at the Hurley facility is small (5 cm/year) and the ground water is relatively deep, the permeable subsurface (60 percent sand, 30 percent silt) may allow leachate caused by infiltrating rainwater to migrate to ground water. Once in ground water, any contamination could migrate in a largely undiluted and unretarded fashion in solution cavities that may exist in the karst underlying the site. Potential drinking water exposures could occur at the nearest downgradient well located less than 100 meters from the Hurley facility.

Using only data on environmental settings, EPA evaluated the ground-water release, transport, and exposure potential of the three facilities that did not provide information on their slag management units. Based on limited data, it appears that the ground-water release, transport, and exposure potential is low at these three facilities.

- At San Manuel, releases to ground water from the slag are not likely because there is essentially no recharge to the aquifer at this location.
- At the Garfield facility, factors that limit the formation and migration of leachate from the slag management unit to the uppermost useable aquifer include the relatively low precipitation (40 cm/year) and net recharge (0.7 cm/year), and the large depth to the useable aquifer (90 meters) that is overlain by clay. The potential for current human health impacts from ground-water contamination is expected to be minimal because, to the best of EPA's knowledge, there are currently no drinking water wells in the useable aquifer within 1.6 km (1 mile) downgradient of the facility. Shallow ground water is hydraulically connected to the Great Salt Lake and is highly saline (not useable). Any leachate from the slag, however, could restrict the potential future uses of the aquifer as a resource.

- At the Amarillo facility, there is a potential for contaminants to migrate into shallow ground water because there is a moderate net recharge (10 cm/yr) and permeable subsurface. However, the potential for drinking water exposure is low because the useable aquifer is very deep, 73 meters below the facility.

Surface Water Release, Transport, and Exposure Potential

Constituents from copper slag could, in theory, enter surface waters by migration of slag leachate through ground water that discharges to surface water, or direct overland (stormwater) run-off of dissolved or suspended slag materials. The concentrations of several constituents detected in copper slag leachate tests (lead, copper, arsenic, molybdenum, cadmium, and to a lesser extent, mercury, iron, barium, chromium, manganese, and zinc) confirm that the potential exists for slag contaminants to migrate into surface water in a leached form. The potential for overland release of copper slag particles to surface waters is limited considerably by the generally large size and the glassy form of the slag: the solidified mass of slag as well as the large chunks of crushed slag are not readily eroded. A small fraction of the slag material, however, may consist of fragments that are small enough to be erodible. Only particles that are 0.1 mm or less in size tend to be appreciably erodible,¹⁶ and only a very small fraction of the copper slag solids are expected to be in this size range.

Exhibit 6-6 summarizes the characteristics of each of the ten copper facilities that affect the surface water release, transport, and exposure potential of copper slag. Based on environmental settings of the facilities and the presence of stormwater run-on/run-off controls at the copper slag management units, the potential for surface water contamination and human exposure due to releases from copper slag at the ten facilities can be summarized as follows:¹⁷

- Copper slag piles at Claypool and Hurley have a low potential for causing surface water contamination because the facilities are very far from any streams, rivers, or lakes (at least 24 km).
- At Phelps Dodge/El Paso and Playas, overland releases are limited by low precipitation and gentle topographic slopes in the areas, as well as stormwater run-off controls at Phelps Dodge/El Paso. Episodic releases are not of concern because neither facility is located in a 100-year floodplain or in areas prone to high snow accumulation and sudden snow-melts. Given the very low potential for ground-water contamination at these sites, it is very unlikely that any contaminants originating from on-site slag management units could seep through ground water and discharge into the Rio Grande river located 550 meters from Phelps Dodge/El Paso or Playas Lake located 480 meters from the Playas facility.
- The potential for overland releases to surface water at the Hayden facility is limited by moderate rainfall (50 cm/year), gentle topographic slope, and the presence of stormwater run-on/run-off controls. Releases to the nearby Gila River could occur, however, by seepage of contaminants to the surficial aquifer that may discharge to the river, although there appears to be a low potential for shallow ground-water contamination at this facility (see above). Because the river has a moderate flow rate (170 mgd), any seepage entering the river will be only moderately diluted. The potential for human exposures to any surface water contamination caused by the Hayden facility is currently minimal because the Gila River is not used for drinking water within 24 km downstream.
- Assuming there are no stormwater run-on/run-off controls at the San Manuel facility's slag pits, there is a potential for overland releases to the San Pedro River located 790 meters away because of the moderate rainfall (50 cm/year) and moderately steep slope (2 to 6%) in the area. Releases via seepage of contaminants through ground water are not expected because there is essentially no recharge to ground water. Any surface water contamination that is not sufficiently diluted

¹⁶ As indicated by the soil erodibility factor of the USDA's Universal Soil Loss Equation.

¹⁷ For three facilities that did not provide information on their temporary slag storage or slag cooling units, the copper slag was assumed to be temporarily accumulated in relatively small slag piles or pits. This assumption may have the effect of overestimating risks because releases are controlled solely by environmental conditions under this scenario.

could threaten aquatic life and restrict potential beneficial uses of the river because the river's low flow rate (0.08 mgd) will not rapidly dilute contaminants. Currently, there are no drinking water intakes from the river within 24 km.

- At the Amarillo facility, it is possible for slag contaminants to migrate through shallow ground water that may discharge to a nearby playa lake because of the moderate rainfall, moderate net recharge, and permeable subsurface in the area (i.e., factors that enable leachate from the slag pile to migrate to shallow ground water). Routine and episodic overland releases are less likely because the rainfall is moderate, and the facility is not located in a 100-year floodplain. Water is present in the lake only intermittently, but when present, the water may be used for livestock watering.
- The Garfield facility is located approximately 300 meters from the Great Salt Lake. Routine overland releases of slag contaminants to the lake are limited by the gentle topographic slope (0 to 2%) and the relatively low amount of precipitation in the area (40 cm/year). Episodic overland releases could occur, however, in the event of a flood (the facility is located in a 100-year floodplain) and sudden snow-melt (maximum snow accumulation is 102 cm). It is also possible for slag contaminants to reach the lake by seeping through ground water, although the potential for contaminant migration via ground water appears low. Any releases to the Great Salt Lake from the slag at this facility have a low potential for adversely affecting human health because the lake is not used for drinking water.
- The potential for release to surface water is relatively high at the ASARCO/El Paso facility; overland releases from the slag piles to the Rio Grande river (76 meters from the facility) have been documented (see damage cases section). Any contaminants reaching the river are likely to be diluted in the river's large flow (520 mgd). If sufficient dilution did not occur, the contamination could threaten aquatic life and the potential beneficial uses of this river, as well as pose human health risks, because there is a drinking water intake that serves almost 500,000 people approximately 4.3 km downstream of the facility.
- The potential for release of contaminants to surface water is also relatively high at the White Pine facility. Releases via seepage of contaminants through ground water could occur at White Pine because, as discussed above, some seepage from the pile could migrate to the shallow aquifer that probably discharges to the river. Although unlikely, episodic overland releases to the nearby river located 120 meters from the facility could also occur due to sudden snow-melts because the facility is located in an area with high snow accumulation (94 cm maximum). Routine overland releases, however, are limited by stormwater run-on/run-off controls and the moderate precipitation (73 cm/year) and slope in the area. Current human exposures to any surface water contamination caused by the White Pine facility are possible because there is an intake at a point 5.5 km downstream.

Air Release, Transport, and Exposure Potential

Because all of the constituents of concern are nonvolatile, copper slag contaminants can only be released to air in the form of dust particles. Dust can be either blown into the air by wind or suspended in air by slag dumping and crushing operations. Factors that affect the potential for such airborne releases include the particle size of copper slag, the height and exposed surface area of the slag piles, the slag moisture content, the use of dust suppression controls, and local wind speeds. The potential for exposure to airborne dust depends on the proximity of the slag piles to people.

The form of copper slag -- a solidified glassy mass that, even when crushed, consists of large particles such as gravel or cobbles -- significantly limits the potential for release of airborne dust. In general, particles that are ≤ 100 micrometers (μm) in diameter are wind suspendable and transportable. Within this range, however, only particles that are ≤ 30 μm in diameter can be transported for considerable distances downwind, and only particles that are ≤ 10 μm in diameter are respirable. The vast majority of copper slag is substantially larger than 100 μm and thus should not be suspendable, transportable, or respirable. It is likely that only a very small fraction of the slag will be weathered and aged (or crushed) into smaller particles that can be suspended in air and cause airborne exposures and related impacts.

Other factors that affect the potential for airborne release and exposure vary on a site-specific basis, though not to a large extent, as follows:

- At the Hayden, Hurley, and Claypool facilities, the slag piles range from approximately 6.9 to 30 hectares (17 to 64 acres) in area and are 12 to 46 meters high. These piles are not covered with either vegetation or a synthetic material, and the facilities do not use any dust suppression controls, such as sprinkling water on the piles. The number of days with rain, which may suppress dust, is also small (43 to 50 days/yr). As a result, the surfaces of the slag piles are expected to be dry most of the time. Although there are surely short term gusts of stronger winds, average wind speeds at these facilities range from 3.4 to 4.8 m/s, which are strong enough to produce wind erosion of any fine particles. Any windblown dust could lead to potential exposures at Hayden, Hurley, and Claypool because at all three facilities, the nearest residence in a predominant wind direction is less than 100 meters away and the population within 1.6 km (1 mile) ranges from 1,000 to 5,500.
- At the Playas facility, the potential for airborne release is similar to the three facilities discussed above. However, the potential for exposures is lower because the nearest residence is 3.7 km away and there is no population within 1.6 km.
- The slag pile at the White Pine facility covers an area of 60 acres, is 3 meters high, and is uncovered. Although the pile is not currently watered for the purpose of dust suppression, there is a moderate number of days that have a small amount of precipitation (116 days/yr) that should help keep the slag moist part of the time. Average wind speeds range up to 4.7 m/s, though stronger winds occur on a short term basis. If airborne dust is released, it could lead to potential exposures at the nearest residence 730 meters from the facility, and could result in 1,200 people within 1.6 km (1 mile) of the facility being exposed.
- At the Asarco/El Paso and Phelps Dodge/El Paso facilities, the slag piles are relatively small (6 and 1 meter high, covering 0.8 hectares and 809 m^2 (2 and 0.2 acres)), making the exposed area of the piles much smaller than the piles at the other facilities. Nevertheless, the small number of days of precipitation to help keep dust down (41 days/yr) and average wind speeds of up to 5.1 m/s, which are strong enough to produce wind erosion of any fine particles, could allow airborne dusting. Both facilities have a residence within 100 meters of their boundaries where potential exposures could occur. There are 40,000 people living within 1.6 km (1 mile) of the Phelps Dodge plant and roughly 500 people within this distance of the Asarco facility.
- For the three facilities that did not provide information on their slag management units (Garfield, San Manuel, and Amarillo), factors such as low number of days of precipitation (47 to 89 days/yr) and average wind speeds of 4.8 to 6.6 m/s, which are strong enough to blow fine particles into the air, indicate that airborne releases could occur. All three facilities have a residence within 1.6 km (1 mile) of their borders where potential exposures could occur. The potential for exposure is highest at Garfield (which has 10,000 people within 1.6 km and the nearest residence located 900 meters away) and at San Manuel (which has 5,000 people within 1.6 km and the nearest residence located 330 meters away). At the Amarillo facility, on the

other hand, there are only 5 people within 1.6 km of the facility and the nearest residence is 760 meters away.

Proximity to Sensitive Environments

As summarized in Exhibit 6-6, seven of the ten copper facilities that generate copper slag are located in or near environments that are either vulnerable to contamination or have high resource value.

- The Playas facility is located within 9 miles of a habitat for an endangered species, the New Mexico Ridge-Nosed Rattlesnake. Given this distance from the site, releases of copper slag contaminants from the facility are not likely to affect this habitat.
- The Asarco/El Paso, Garfield, and Hurley facilities are located in 100-year floodplains, which creates the potential for large, episodic releases caused by flood events (although such releases are generally unlikely).
- The Garfield facility is located in a wetland area (defined here to include marshes, swamps, and bogs). Wetlands are commonly entitled to special protection because they provide habitats for many forms of wildlife, purify natural waters, provide flood and storm damage protection, and afford a number of other benefits.
- The Hurley facility is located in an area of karst terrain, characterized by sinkholes and underground cavities developed in water-soluble rock (such as limestone or dolomite). Solution cavities could permit any ground-water contamination originating from the on-site slag to migrate in a largely unattenuated and undiluted fashion.
- The White Pine facility is located in a National Forest, and the Claypool facility is located within a mile of a National Forest. Any contamination originating from slag at these sites could have an adverse effect on the habitats and resources provided by these forests.
- The White Pine, Claypool, Phelps Dodge/El Paso, Hurley, and Playas facilities are located in fault zones. This creates the potential for damage to containment systems for slag piles at these sites in the unlikely event of an earthquake.

Risk Modeling

Based on the preceding analysis of the intrinsic hazard of copper slag and the potential for slag contaminants to be released into the environment, the Agency ranked copper slag as having a relatively high potential to cause human health and environmental risks (compared to the other mineral processing wastes studied in this report). Therefore, the Agency used the model "Multimedia Soils" (MMSOILS) to estimate ground-water, surface water, and air pathway risks caused by the management of copper slag. Rather than model all ten sites that generate and manage the slag individually, EPA modeled a hypothetical composite site that consists of selected features from three different sites. In particular, EPA modeled:

- The median constituent concentrations in copper slag solids as measured at the facility at Garfield, UT, and the median constituent concentrations in copper slag leachate as measured at the facility in Playas, NM. In general, the concentrations of most constituents measured in the slag and slag leachate at these facilities were higher than those measured at other facilities. The median concentrations at Garfield and Playas, however, are only slightly greater than the medians observed elsewhere and thus reasonably represent copper slag across the industry.
- The slag quantity, management practice, and environmental/exposure setting at the facility in White Pine, MI. Of the ten facilities that generate and manage the slag, this facility maintains one of the largest slag piles and has environmental and exposure characteristics most likely to lead to high risks. These characteristics include the highest net recharge of all ten sites, a relatively shallow water table, a useable aquifer beneath the site, a relatively nearby and small stream that may be used for drinking water, and relatively nearby residents that could be exposed to windblown dust. Although the slag pile at White Pine is equipped with stormwater run-on/run-off controls, EPA conservatively modeled the pile as if it had no controls to limit erosion.

By combining these generally typical waste stream contaminant concentrations with a set of "conservative" environmental and exposure characteristics into one modeling scenario, the Agency believes that the risk estimates presented below represent a reasonable upper bound of actual risks at the ten active primary copper facilities.

Ground-Water Risks

Using the combined site features as described above, EPA modeled potential releases to ground water from a hypothetical copper slag pile. EPA considered in this analysis the potential releases of arsenic, cadmium, chromium, and molybdenum, which are the primary constituents of potential concern through the ground-water pathway based on the analysis of copper slag leachate. In addition, EPA modeled the risks caused by potential releases of lead to ground water, because along with cadmium, lead was detected in EP leach tests in concentrations that exceeded the EP toxicity criterion. The Agency predicted the concentrations of these constituents at the following locations downgradient from the slag pile: the facility property boundary (150 meters), the nearest surface water body (120 meters), and, to analyze how far a contaminant plume might spread, the distances of 50 and 500 meters. At each of the locations, the Agency compared the predicted contaminant concentrations to cancer risk levels, threshold concentrations that could cause noncancer effects, drinking water maximum contaminant levels (MCLs), and guidelines for irrigation and livestock waters recommended by the National Academy of Sciences (NAS).

All of the Agency's predicted concentrations of arsenic, cadmium, chromium, molybdenum, and lead in ground water were at least two orders of magnitude below the various criteria, even at the closest point modeled (50 meters downgradient from the slag pile). The predicted concentration of arsenic in ground water 50 meters downgradient and at the property boundary, where the water conceivably could be ingested by a member of the general public, would cause a lifetime cancer risk of less than 1×10^{-10} (i.e., the chance of getting cancer would be less than one in ten billion if the water was ingested over a 70-year lifetime). Only arsenic and cadmium were predicted to migrate to the water table within the modeling time frame that was considered (200 years). EPA predicted that it would take chromium and molybdenum roughly 470 years to migrate from the slag pile down to the water table, while lead released from the slag pile was predicted to be bound up in the unsaturated zone for over 1,000 years.

Surface Water Risks

To evaluate surface water risks, EPA modeled a $1.8 \text{ m}^3/\text{sec}$ ($65 \text{ ft}^3/\text{sec}$) stream located 120 meters from a 24 hectares (60-acre) slag pile, which are roughly the conditions that currently exist at the facility in White Pine, MI. Considering the annual loading of contaminants to the stream via ground-water seepage and erosion, the Agency predicted the surface water concentrations of the following constituents after they have been fully mixed in the stream's annual average flow: arsenic, cadmium, chromium, copper, iron, lead, mercury, molybdenum, nickel, and zinc. EPA then compared the predicted concentrations of these constituents to cancer risk levels, noncancer effect thresholds, MCLs, freshwater ambient water quality criteria (AWQCs) for chronic exposures, and the NAS recommended guidelines for livestock and irrigation waters. Note that this approach does not account for removal, via treatment, of constituents in drinking water, and is thus conservative for that pathway.

EPA's predicted concentrations of cadmium, chromium, nickel, and zinc in the stream were at least two orders of magnitude below the various criteria. The estimated concentration of mercury also did not exceed any of the criteria, although it was within a factor of 0.7 times the AWQC.¹⁸ The estimated concentrations of arsenic, copper, lead, iron, and molybdenum exceeded at least one of the criteria. All of these constituents were predicted to migrate into the stream by erosion of fine particles from the slag pile (seepage of contaminants into ground water with subsequent discharge into the stream resulted in a negligible pollutant loading). In particular:

- The estimated concentration of arsenic in the stream would cause a lifetime cancer risk of 6×10^{-5} if ingested over 70 years. This arsenic concentration, however, is two orders of magnitude below the MCL.
- The predicted concentration of copper equaled the NAS recommended guideline for irrigation water and exceeded the AWQC by a factor of 65. Research has shown that if water with copper concentrations in excess of the NAS guideline is used continuously for irrigation, it

¹⁸ This estimated mercury concentration in the stream is considered very conservative because it is based on a non-detected mercury concentration in copper slag solids. For the purpose of this analysis, EPA assumed that mercury is present in the slag solids in a concentration that equals the full detection limit.

could be toxic to plants. Exceedance of the AWQC indicates that the copper concentrations in waters near copper slag piles could be harmful to aquatic organisms.

- The estimated concentration of lead exceeded the proposed revised MCL by a factor of 1.1 and the AWQC by a factor of 1.7. This lead concentration could cause a variety of subtle biochemical and cellular effects if consumed on a long-term basis, and adversely affect the health of aquatic organisms living in affected waters.
- The estimated concentration of iron exceeded the MCL by a factor of 3.7 and the AWQC by a factor of 1.1. Concentrations of iron in excess of the MCL could cause objectionable tastes and stains. Exceedance of the AWQC indicates that the iron concentrations in waters near copper slag piles could be harmful to aquatic organisms.
- The estimated concentration of molybdenum exceeded the NAS irrigation guideline by a factor of 2.1. Although molybdenum concentrations in excess of the NAS guideline have not been shown to be toxic to plants, they can be toxic to animals that forage on plants irrigated with the water.

Of the constituents that were modeled, only mercury is recognized as having the potential to biomagnify (concentrate in the tissue of organisms higher in the food chain). However, considering the low mercury concentrations that were predicted, EPA does not expect adverse effects due to biomagnification. Cadmium, lead, and zinc (and to a lesser extent, the other constituents) may bioaccumulate in the tissue of freshwater fish that could be consumed by people. However, based on a "worst-case" exposure analysis using the predicted surface water contamination caused by copper slag, EPA does not believe that the ingestion of fish from the affected water would pose a health threat.

The Agency believes that these estimates reasonably represent the conditions that could occur at the facility in White Pine, MI if the on-site slag pile was not equipped with stormwater run-off controls. Except for the contaminant concentrations in the slag and slag leachate, which were measured at the Garfield and Playas facilities, all of the site-specific conditions that were modeled are generally representative of the White Pine facility. Furthermore, as discussed above, the concentrations that were modeled are approximately equal to median concentrations measured in copper slag at all ten facilities (i.e., they are reasonably representative of the concentrations observed across the industry). However, because the slag pile is equipped with run-off controls, the Agency believes the above estimates represent conservative upper bound risks at White Pine, as well as at the other nine active copper facilities. The other facilities are located in much more arid and remote areas where there is a smaller potential for contaminant releases and exposures via the surface water pathway (as described above in the analysis of release, transport, and exposure potential).

Air Risks

EPA modeled the release of windblown dust from the slag pile and the associated inhalation risks of a hypothetical maximum exposed individual assumed to live 90 meters away in the predominant wind direction. The distance of 90 meters was chosen because, based on an analysis of the population distribution around the ten active copper facilities, it is a typical "close" distance between copper slag piles and nearest residences. For this distance, the Agency predicted the airborne concentrations and inhalation risks of arsenic, chromium, and nickel, which are all carcinogens through the inhalation pathway (chromium was conservatively assumed to exist in the carcinogenic hexavalent form). In general, the Agency's approach for modeling releases was very conservative because it assumed that there is an "unlimited reservoir" of fine particles that can be blown into the air from copper slag piles. As discussed previously, copper slag actually has limited wind erosion potential because the vast majority of slag on the piles consists of large particles that are not suspendable or transportable at typical wind speeds.

Even with this conservative approach, risks caused by the inhalation of dust from the hypothetical copper slag pile were predicted to be low. At the hypothetical residence assumed to be 90 meters from the slag pile, the total lifetime cancer risk caused by the inhalation of arsenic, chromium, and nickel was estimated to be 1×10^{-6} . Considering the conservative modeling approach that was used, EPA believes that this estimate represents a reasonable upper bound of the inhalation risks caused by copper slag piles at the ten active facilities.

6.3.2 Risks Associated With Copper Slag Tailings

Any potential danger to human health and the environment from copper slag tailings depends on the presence of toxic constituents in the tailings that may pose a risk and the potential for exposure to these constituents based on facility setting and management practices. These factors are discussed separately below.

Constituents of Concern

Using the same process outlined above for copper slag, EPA identified chemical constituents in the copper slag tailings that may pose a risk by collecting data on the composition of slag tailings, and evaluating the intrinsic hazard of the slag tailings' chemical constituents.

Data on Copper Slag Tailings Composition

EPA's characterization of copper slag tailings and its leachate is based on data from two sources: (1) a 1989 sampling and analysis effort by OSW; and (2) industry responses to a RCRA §3007 request in 1989. These data provide information on the concentrations of 20 metals, radium-226, uranium-238, and sulfate in total solids and/or leach test analyses. Two of the three facilities that generate the slag are represented by these data: Kennecott in Garfield, Utah, and Magma Copper Company in San Manuel, Arizona.

Concentrations in total samples of the slag tailings are generally consistent for most constituents across all data sources and facilities. The exceptions are for lead -- concentrations of lead in tailings samples from the two facilities differed by over three orders of magnitude; and molybdenum -- the concentration of molybdenum in slag tailings from the Garfield facility was three orders of magnitude higher than the concentration measured in tailings from the San Manuel facility. Concentrations from leach test analyses of the slag tailings are consistent across the data sources, types of leach tests (i.e., EP, SPLP, and TCLP), and facilities.

Identified Constituents of Concern

Exhibits 6-7 and 6-8 present the results of the comparisons for copper slag tailings total analyses and leach test analyses, respectively, to the risk screening criteria. These exhibits list all constituents for which sample concentrations exceed a screening criterion.

From the 21 constituents analyzed in copper slag tailings solids, only arsenic, chromium, and lead concentrations exceed the screening criteria (see Exhibit 6-7). Arsenic and chromium concentrations in the slag tailings exceed the inhalation pathway screening criteria. This indicates that if the slag tailings are blown into the air as dust and inhaled in a concentration that equals the National Ambient Air Quality Standard for particulate matter, these two constituents may be present in concentrations that could cause a cancer risk of greater than 1×10^{-5} . Arsenic and lead concentrations in the tailings solids exceed the incidental ingestion screening criteria. This means that, if the tailings are incidentally ingested on a routine basis (e.g., if children playing on abandoned waste piles inadvertently ingest the tailings), arsenic would pose a cancer risk of 1×10^{-5} or more, while lead could cause adverse noncancer effects. All three constituents were detected in more than 90 percent of the samples analyzed at concentrations exceeding the screening criteria. All three constituents were also detected in concentrations that exceed the screening criteria by a factor of ten or more.

Based on a comparison of leach test concentrations of 22 constituents to the surface and ground-water pathway screening criteria (see Exhibit 6-8), only 7 constituents (copper, molybdenum, arsenic, lead, silver, nickel, and mercury) were detected at levels above the screening criteria. All of these constituents are metals or other inorganics that do not degrade in the environment. Arsenic exceeded the screening criteria in 12 out of 13 samples, and the highest measured arsenic concentration exceeds the drinking water criterion by a factor of 900. Nickel and mercury, on the other hand, were found to exceed the screening criteria in only 20 to 30 percent of the samples analyzed, and only by a factor of 2 or less. Despite these exceedances of the screening criteria, no constituents were detected in the leachate in concentrations that exceed the EP toxicity regulatory levels.

These exceedances indicate the potential for the following types of impacts under the following conditions:

- Concentrations of arsenic and copper in the slag tailings leachate are high enough that, if the leachate is released to ground water and diluted only by a factor of 10 during migration to a drinking water well, long-term ingestion of the water could cause adverse health effects.
- Concentrations of copper, arsenic, silver, nickel, and mercury in slag tailings leachate could present a threat to aquatic ecological receptors if it migrates (with a 100-fold dilution) to surface waters.
- If the leachate is released and diluted by a factor of ten or less, copper, molybdenum, arsenic, and lead concentrations could exceed drinking water maximum contaminant levels or guidelines for irrigation water.

These exceedances of the risk screening criteria, by themselves, do not prove that copper slag tailings pose a significant risk. The criteria exceedances outlined above only indicate that the tailings may present a hazard under a set of very conservative, hypothetical exposure conditions. To determine the risks associated with copper slag tailings, therefore, EPA proceeded to the next step of the risk analysis to examine the actual release, transport, and exposure conditions that exist at the facilities that actively generate and manage the tailings.

Release, Transport, and Exposure Potential

The following analysis considers the baseline hazards of copper slag tailings at the three plants of interest in 1988. For this analysis, EPA did not consider the hazards of off-site disposal or use of the tailings because the tailings currently are never disposed of or used off-site (although slag tailings have been used off-site for construction purposes in the past and conceivably could be used again in the future). Alternative

Exhibit 6-7
Potential Constituents of Concern in Copper Slag Tailings Solids^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Human Health Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Arsenic	26 / 27	Ingestion* Inhalation*	26 / 27 26 / 27	1 / 2 1 / 2
Chromium	8 / 9	Inhalation*	8 / 9	1 / 2
Lead	27 / 27	Ingestion	25 / 27	1 / 2

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample.
- (b) Human health screening criteria are based on exposure via incidental ingestion and inhalation. Human health effects include cancer risk and noncancer health effects. Screening criteria noted with an " * " are based on a 1×10^{-6} lifetime cancer risk; others are based on noncancer effects.

Exhibit 6-8
Potential Constituents of Concern in Copper Slag Tailings Leachate^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Copper	3 / 3	Human Health Resource Damage Aquatic Ecological	2 / 3 2 / 3 3 / 3	2 / 2 2 / 2 2 / 2
Molybdenum	2 / 2	Resource Damage	2 / 2	2 / 2
Arsenic ^(c)	12 / 13	Human Health* Resource Damage Aquatic Ecological	12 / 13 9 / 13 7 / 13	2 / 2 1 / 2 1 / 2
Lead ^(c)	9 / 13	Resource Damage	9 / 13	2 / 2
Silver ^(c)	9 / 13	Aquatic Ecological	6 / 13	1 / 2
Nickel ^(c)	2 / 11	Aquatic Ecological	2 / 11	1 / 2
Mercury	1 / 3	Aquatic Ecological	1 / 3	1 / 2

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample. Unless otherwise noted, the constituent concentrations used for this analysis are based on EP leach test results.
- (b) Human health screening criteria are based on cancer risk or noncancer health effects. "Human health" screening criteria noted with an " * " are based on a 1×10^{-6} lifetime cancer risk; others are based on noncancer effects.
- (c) Data for this constituent are from SPLP leach test results.

practices for managing the tailings are discussed in Section 6.5. In addition, the following analysis does not consider the risks associated with variations in waste management practices or potentially exposed populations in the future, because of a lack of information on possible future conditions.

Ground-Water Release, Transport, and Exposure Potential

As discussed in the preceding section, EPA and industry test data show that several constituents are capable of leaching from copper slag tailings in concentrations that exceed the risk screening criteria. Considering only those constituents that are expected to be mobile in ground water (given the existing tailings management practices and neutral pH of the leachate), slag tailings contaminants that pose the primary potential threat are arsenic, mercury, and molybdenum. The ground-water release and transport potential of copper slag tailings at the three facilities depends on site-specific management practices and environmental settings.

The single tailings pond at the White Pine facility is underlain by recompacted local clay and in-situ clay that helps limit leachate from the pond reaching the underlying aquifer. Nevertheless, the large quantity of standing liquid in the pond (the pond is 16 meters deep and covers 972 hectares (2,400 acres)) produces a considerable hydraulic head that could drive leachate from the tailings into the subsurface. Furthermore, any constituents released from the units could be transported readily through the 6 to 12 meters of fractured rock that lies between the pond and the stratum identified as the uppermost aquifer. Any ground-water contamination from the unit, especially arsenic contamination, could restrict the potential future uses of this aquifer. However, the potential for current human health impacts from ground-water contamination is expected to be minimal because, to the best of EPA's knowledge, there are currently no drinking water wells within a mile downgradient of the facility, and the aquifer is not being used as a municipal drinking water supply.

At the Garfield facility, fresh slag tailings are discharged as a slurry to a tailings impoundment. This impoundment is now about 46 meters above the original grade and covers about 2,300 hectares (5,600 acres). Dried tailings are used to form a berm that creates the impoundment into which the slurried tailings are discharged. In theory, tailings contaminants could be released to ground water by seepage of the ponded water or by rain water infiltrating through dry areas of the impoundment. However, factors that limit the migration of leachate from the tailings impoundment to the uppermost useable aquifer include: the precipitation (40 cm/year) and net recharge in the area (0.7 cm/year) are relatively low; and the aquifer is very deep (i.e., 90 meters) and is primarily overlain by a zone of impermeable clay. In addition, the potential for current human health impacts from any contamination from the tailings impoundment, should it occur, appears minimal because there are currently no drinking water wells within a mile downgradient of the facility to the best of EPA's knowledge. The shallow ground water at the site is saline (and generally unuseable) because it is hydraulically connected with the Great Salt Lake.

The five tailings ponds at the San Manuel plant are not lined and have no leachate collection systems or other controls to limit releases to ground water. These ponds, which are 40 to 60 meters deep and cover anywhere from 140 to 330 hectares (350 to 820 acres), may have quantities of supernatant liquids that potentially provide sufficient hydraulic head to drive contaminants to the underlying aquifer. However, the uppermost useable aquifer beneath this facility is located 140 meters beneath the tailings ponds and is separated by an intervening alluvial aquifer. Ground-water monitoring data indicate that contamination of the useable aquifer has occurred at this site. Sulfate, which is present in the tailings but was not measured in the tailings leachate, has been detected downgradient of the facility at levels exceeding drinking water standards. (The Agency's review of State and EPA regional files did not provide evidence that this ground-water contamination is attributable to slag tailings management.) Any contaminant migration from the slag tailings into the uppermost useable aquifer has a high potential for posing current human health risks and restricting potential future uses of the ground water because approximately 4,000 people rely on the aquifer for drinking water from a municipal well located only 150 meters downgradient from the facility.

Surface Water Release, Transport, and Exposure Potential

Constituents of concern in copper slag tailings theoretically could enter surface waters by migration of slag tailings leachate through ground water that discharges to surface water, or by direct overland (stormwater) run-off of dissolved or suspended slag tailings constituents. As discussed above, the following constituents that are mobile in ground water leach from the slag tailings at levels that potentially could pose human health or aquatic ecological threats or damage surface water resources: molybdenum, arsenic, and mercury. The other constituents in slag tailings could potentially migrate to surface water via overland erosion.

At the White Pine facility, excess water in the tailings pond, which could contain entrained tailings solids, is discharged directly to a river located 120 meters away via a NPDES-permitted outfall. It is also possible for the tailings contaminants to migrate to the river via ground-water seepage. Water quality monitoring in the river has identified cadmium, selenium, copper, and total dissolved solids concentrations in excess of drinking water standards, as well as cadmium, copper, lead, selenium, and zinc levels that exceed the ambient water quality criteria. The slag tailings could be a contributor to this contamination because, based on EPA and industry test data, copper and lead are readily leachable from the tailings. The river near this facility has a relatively low dilution capacity (flow of 42 mgd), and potential drinking water exposures could occur at a water supply intake 5 km downstream (it appears that 25 people rely on this intake). Therefore, if not sufficiently diluted, any contaminants entering the river could potentially harm aquatic life, restrict the future uses of the river as a resource, and pose health risks to existing populations.

At the Garfield facility, the potential for routine overland releases to the Great Salt Lake are limited by the distance to the lake (300 meters), stormwater run-on/run-off controls, the gentle topographic slope (0 to 2 percent), and the relatively low amount of precipitation in the area (40 cm/yr). Although unlikely, episodic overland releases could occur in the event of a flood (the facility is located in a 100-year floodplain). Release of contaminants to surface water is also possible by infiltration of contaminants to the surficial aquifer that is hydraulically connected with the lake. Releases to Great Salt Lake have a low potential for adversely affecting human health because the lake is not used for drinking water.

Contaminants from slag tailings ponds at the San Manuel plant possibly could migrate to the San Pedro River located 790 meters away via seepage to the alluvial aquifer that may discharge to the river. As discussed in the preceding section on ground water, seepage to the surficial aquifer is possible due to the leachability of the waste, lack of ground-water controls, and standing liquids in the ponds. Overland run-off of the tailings could only occur in the event of a major storm causing overflow of tailings from the ponds. Such overflow is unlikely, however, because of the plant's stormwater run-on/run-off controls, low precipitation (50 cm/year) available for run-off, and moderate topographic slope (2 to 6%). The San Pedro River near this facility has a low flow rate (0.08 mgd), which provides only a limited dilution capacity. The river water is used for livestock watering approximately 1.2 km downstream of the facility, but currently, there are no other consumptive uses within 24 km downstream. If not sufficiently diluted, contaminants reaching the river could pose a risk to aquatic organisms and restrict potential uses of the river.

Air Release, Transport, and Exposure Potential

Because all of the constituents of potential concern in copper slag tailings are nonvolatile, the contaminants can be released to air only in the form of dust particles. As presented above, only arsenic and chromium are present in the slag tailings in concentrations that could pose human health risks through inhalation of respirable particles of slag tailings.

In general, particles that are ≤ 100 micrometer (μm) in diameter are wind suspendable and transportable. Within this range, however, only particles that are ≤ 30 μm in diameter can be transported for considerable distances downwind, and only particles that are ≤ 10 μm in diameter are respirable. The slag tailings consist mainly of particles larger than 100 μm in diameter, and therefore, the majority of the slag tailings should not be suspendable, transportable, or respirable. The quantity of tailings disposed and the areal extent of the disposal areas, however, is such that wind transport of fine tailings material does occur if the tailings dry out.

The potential for dust to be blown into the air from the tailings impoundment at the Garfield facility is limited because the facility suppresses dust by periodically moving the location of the discharge of the tailings slurry to keep the surface of the entire impoundment wet. Nevertheless, dusting is possible because dried tailings are piled up and exposed to the wind around the perimeter of the impoundment and the entire impoundment may not always remain wet. In addition, the facility is located in an arid area where there is relatively infrequent rainfall (there are only 89 rainy days/year) and significant evaporation, which is conducive to dusting. In at least one instance, due to a facility shutdown, a large part of the tailings pile surface became dry and tailings dust was released to air whenever the wind speeds exceeded 20 mph. Ambient air quality monitoring at the facility indicated that the National Ambient Air Quality Standards (24-hour average concentration) for respirable particulate matter had been exceeded. Such airborne releases at this facility could lead to potential exposures at the closest residence, approximately 20 meters from the facility, as well as exposures to the 10,000 people that live within 1.6 km of the facility.

At the White Pine and San Manuel facilities, the slag tailings are currently submerged in the ponds, and there are no significant areas of dry tailings from which dust could be blown into the air. The San Manuel facility, however,

is located in a very arid area in which significant evaporation from the tailings ponds is likely after the ponds are closed. This could allow the surface of the tailings to become dry after closure, allowing a small fraction of the tailings (i.e., those particles that are smaller than 100 μm) to be blown in the air as dust.

Proximity to Sensitive Environments

As discussed in the preceding section on copper slag, the White Pine facility is located in a fault zone, which creates the potential for damage to slag tailings containment systems in the unlikely event of an earthquake. The facility is also located in a National Forest; any contamination originating from the White Pine facility, therefore, could endanger the habitats and resources provided by the forest. The Garfield facility is located in a 100-year floodplain, which creates the potential for large episodic releases of tailings due to floods, and in a wetland. Any contamination originating from the Garfield facility could adversely affect the habitats and special functions provided by the wetland. The San Manuel facility is not located in or within one mile of an environment that is particularly vulnerable to contamination or has a high resource value.

Risk Modeling

Based upon the evaluation of intrinsic hazard, the descriptive analysis of factors that influence risk, the risk modeling results for other mineral processing wastes examined in this report, and upon a comprehensive review of information on documented damage cases (presented in the next section), EPA has concluded that the potential for slag tailings to impose significant risk to human health or the environment if managed according to current practice is generally low. Therefore, the Agency has not conducted a quantitative risk modeling exercise for this waste.

6.3.3 Risks Associated With Calcium Sulfate Sludge

This section discusses the constituents in calcium sulfate sludge that are potentially of concern, and the potential for exposure to these constituents based on facility setting and management practices.

Constituents of Concern

EPA identified chemical constituents in the calcium sulfate sludge that may pose a risk using the same process outlined above for copper slag.

Data on Calcium Sulfate Sludge Composition

EPA's characterization of calcium sulfate sludge and its leachate is based on data from two sources: (1) OSW's 1989 sampling and analysis effort; and (2) industry responses to a §3007 request in 1989. These data provide information on the concentrations of 20 metals, ammonia, and nitrate in total and leach test analyses. Both facilities that currently generate the sludge are represented by these data: Asarco in Hayden, Arizona, and Kennecott in Garfield, Utah.

Concentrations in total analyses of the calcium sulfate sludge are consistent for most constituents across all data sources and facilities. Silver concentrations in calcium sulfate sludge at the Garfield facility (OSW data), however, are more than three orders of magnitude lower than silver concentrations in sludge at the Hayden facility (industry data). Concentrations from leach test analyses of the calcium sulfate sludge generally are also consistent across the data sources, types of leach tests (i.e., EP, SPLP, and TCLP), and facilities. Copper and mercury concentrations in leachate from the sludge as determined by EP leach test analyses, however, are more than three orders of magnitude higher than the SPLP leach test concentrations.

Identified Constituents of Concern

Exhibits 6-9 and 6-10 present the results of the comparisons for calcium sulfate sludge total analyses and leach test analyses, respectively, to the screening criteria. These exhibits list all constituents for which sample concentrations exceed a screening criterion.

Exhibit 6-9
Potential Constituents of Concern in Copper CaSO₄ Sludge Solids^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Human Health Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Arsenic	7 / 7	Ingestion* Inhalation*	7 / 7 7 / 7	2 / 2 2 / 2
Lead	9 / 9	Ingestion	7 / 9	3 / 3
Cadmium	7 / 9	Inhalation* Ingestion	6 / 9 6 / 9	2 / 3 2 / 3
Antimony	5 / 7	Ingestion	5 / 7	1 / 2
Silver	5 / 6	Ingestion	3 / 6	1 / 2
Copper	9 / 9	Ingestion	4 / 9	1 / 3

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample.
- (b) Human health screening criteria are based on exposure via incidental ingestion and inhalation. Human health effects include cancer risk and noncancer health effects. Screening criteria noted with an "*" are based on a 1×10^{-6} lifetime cancer risk; others are based on noncancer effects.

Exhibit 6-10
Potential Constituents of Concern in Copper CaSO₄ Sludge Leachate^(a)

Potential Constituents of Concern	No. of Times Constituent Detected/No. of Analyses for Constituent	Screening Criteria ^(b)	No. of Analyses Exceeding Criteria/ No. of Analyses for Constituent	No. of Facilities Exceeding Criteria/ No. of Facilities Analyzed for Constituent
Arsenic	8 / 8	Human Health Resource Damage Aquatic Ecological	8 / 8 8 / 8 8 / 8	2 / 2 2 / 2 2 / 2
Selenium	7 / 8	Human Health Resource Damage Aquatic Ecological	7 / 8 7 / 8 7 / 8	1 / 2 1 / 2 1 / 2
Lead	8 / 8	Human Health Resource Damage Aquatic Ecological	8 / 8 8 / 8 8 / 8	2 / 2 2 / 2 2 / 2
Cadmium	8 / 8	Human Health Resource Damage Aquatic Ecological	7 / 8 7 / 8 7 / 8	2 / 2 2 / 2 2 / 2
Copper	8 / 8	Human Health Resource Damage Aquatic Ecological	7 / 8 7 / 8 7 / 8	2 / 2 2 / 2 2 / 2
Mercury	8 / 8	Human Health Resource Damage Aquatic Ecological	4 / 8 5 / 8 6 / 8	1 / 2 1 / 2 1 / 2
Nickel	1 / 2	Human Health Resource Damage Aquatic Ecological	1 / 2 1 / 2 1 / 2	1 / 2 1 / 2 1 / 2
Silver	6 / 8	Resource Damage Aquatic Ecological	5 / 8 6 / 8	1 / 2 1 / 2
Zinc	2 / 2	Human Health Resource Damage Aquatic Ecological	1 / 2 1 / 2 2 / 2	1 / 2 1 / 2 2 / 2
Antimony	1 / 2	Human Health	1 / 2	1 / 2
Aluminum	2 / 2	Aquatic Ecological	2 / 2	2 / 2
Manganese	2 / 2	Resource Damage	1 / 2	1 / 2

- (a) Constituents listed in this table are present in at least one sample from at least one facility at a concentration that exceeds a relevant screening criterion. The conservative screening criteria used in this analysis are listed in Exhibit 2-3. Constituents that were not detected in a given sample were assumed not to be present in the sample. The constituent concentrations used for this analysis are based on EPA leach test results.
- (b) Human health screening criteria are based on cancer risk or noncancer health effects. "Human health" screening criteria noted with an "r" are based on a 1×10^{-6} lifetime cancer risk; others are based on noncancer effects.

Of the 22 constituents analyzed in total analyses of copper calcium sulfate sludge, only 6 (arsenic, lead, cadmium, antimony, silver, and copper) are present in concentrations that exceed the conservative screening criteria. Among these six constituents, arsenic, lead, cadmium, and antimony present the greatest potential concern because they were detected in most of the samples analyzed (75 to 100 percent), and their concentrations in most analyses (approximately 66 to 100 percent) exceed the screening criteria. Arsenic, lead, and cadmium concentrations also exceed the criteria by the widest margins, ranging from 20 to 25,000 times the criteria.

- Arsenic, lead, cadmium, antimony, silver, and copper concentrations could cause adverse health effects if a small quantity of the sludge or soil contaminated with it is incidentally ingested on a routine basis (e.g., if children playing on abandoned sludge disposal areas inadvertently ingest some of the sludge solids).
- If dust from the sludge is blown into the air in a concentration that equals the National Ambient Air Quality Standard for particulate matter, arsenic and cadmium concentrations could pose a cancer risk exceeding 1×10^{-5} if inhaled by nearby individuals. However, as discussed in more detail in the next section, such large releases and exposures to windblown dust are considered very unlikely given the surface crust that forms on the dried sludge.

Based on a comparison of EP leach test concentrations of 20 constituents to surface and ground-water pathway screening criteria (see Exhibit 6-10), 12 constituents (i.e., arsenic, selenium, lead, cadmium, copper, mercury, nickel, silver, zinc, antimony, aluminum, and manganese) were detected at levels above the criteria. Arsenic, selenium, and lead were detected in most (if not all) of the samples analyzed in concentrations that exceed all three screening criteria (i.e., for human health, resource damage, and aquatic ecological threats). All but aluminum, antimony, and zinc exceed the criteria by a factor of 10 or more; maximum arsenic, copper, mercury, and selenium concentrations exceed one of the criteria by more than a factor of 100. Arsenic exceeds the screening criteria by the widest margin, up to a factor of 350,000. Arsenic, selenium, and cadmium were also measured in EP leachate in concentrations above the EP toxicity regulatory levels. All of these constituents that exceed the screening criteria are persistent in the environment (i.e., they do not degrade).

These exceedances have the following implications:

- If sludge leachate is released to ground water and diluted by a factor of 10 or less during migration to a drinking water well, concentrations of arsenic, selenium, lead, cadmium, copper, mercury, nickel, antimony, and zinc in the ground water could cause adverse health effects if ingested.
- Arsenic, selenium, lead, cadmium, copper, mercury, nickel, silver, zinc, and aluminum in the calcium sulfate sludge leachate could present a threat to aquatic organisms if it migrates (with a 100-fold dilution) to surface waters.
- If the leachate is released to ground water and diluted by a factor of 10 or less, arsenic, selenium, lead, cadmium, copper, mercury, nickel, silver, zinc, and manganese concentrations could exceed drinking water maximum contaminant levels or irrigation guidelines.

Concentrations above the screening criteria do not prove that the sludge poses a significant hazard, but rather indicate that the sludge could pose risks under a set of very conservative, hypothetical exposure conditions. To examine the potential for the sludge to pose hazards in greater detail, EPA analyzed the actual release, transport, and exposure conditions that exist at the two facilities that actively generate and manage the sludge.

Release, Transport, and Exposure Potential

This analysis considers the baseline hazards of the sludge as it was generated and managed at the two copper plants of concern in 1988. It does not consider the hazards associated with off-site disposal or use because the sludge is managed only on-site and is not likely to be disposed or used off-site in the future. In addition, the following analysis does not consider the risks associated with variations in waste management practices or potentially exposed populations in the future because of a lack of information on possible future conditions.

Ground-Water Release, Transport, and Exposure Potential

The calcium sulfate sludge is a solid material, but is generated as a thick slurry mixed with water (i.e., a slurry with a relatively high solids fraction). After being discharged to surface impoundments, the sludge solids settle out and, in the arid settings of Garfield, UT and Hayden, AZ, the supernatant liquid is generally lost to evaporation. EPA and industry test data show that 12 constituents are capable of leaching from calcium sulfate sludge in concentrations above

the risk screening criteria. Considering only those sludge constituents that are expected to be mobile in ground water if released, the contaminants that pose the primary potential human health and ground-water resource damage threat are arsenic, selenium, cadmium, and mercury.

The two surface impoundments used to manage the sludge at the Garfield facility hold from 25 to 34 million gallons of the waste sludge. The surface impoundments are underlain by in-situ clay, and the water table is roughly 8 meters deep. The uppermost useable aquifer is approximately 90 meters beneath the base of the impoundments. Significant migration of sludge contaminants into ground water at this site appears unlikely because of the very arid setting -- the liquid that is discharged to the impoundment along with the sludge is expected to quickly evaporate and little precipitation and recharge is available to carry contaminants into the subsurface. Even if releases from the calcium sulfate sludge at this facility did occur, the potential for current adverse human health impacts appears low because, to the best of EPA's knowledge, there are no downgradient public or private wells within 1.6 km.

At the Hayden facility, the impoundment used to manage the sludge is equipped with a synthetic (asphalt/rubber) liner. In the event of liner failure, seepage could migrate to shallow ground water (located 6 meters beneath the land surface) because the subsurface material is composed mainly of permeable sand (80 percent) with little clay (10 percent). However, the current potential for people to be exposed to such contamination, if it were to occur, is low because facility personnel report that the aquifer under the site is not used for drinking water or any other purpose.

Surface Water Release, Transport, and Exposure Potential

Constituents of potential concern in calcium sulfate sludge, in theory, could enter surface waters by migration of sludge leachate through ground water that discharges to surface water, or by direct overland (stormwater) run-off of dissolved or suspended sludge contaminants. As discussed above, the following constituents that are expected to be mobile in ground water leach from the calcium sulfate sludge at levels above the risk screening criteria: arsenic, selenium, cadmium, and mercury. Other sludge constituents potentially could migrate to surface waters via stormwater runoff.

The potential for routine overland run-off of the sludge contaminants to surface waters due to overflow from the sludge management ponds at both facilities is limited by stormwater run-on/run-off controls at the units, low to moderate precipitation (40 to 50 cm/yr), and gentle topographic slopes at the sites (up to 2 percent). Other site-specific factors include:

- The sludge impoundments at the Garfield facility are located approximately 3,300 meters from the Great Salt Lake. Given this great distance, it is unlikely that contaminants could enter the lake in potentially harmful concentrations via seepage to ground water. Furthermore, any releases to surface water at this facility have a low potential for adversely affecting human health because the Great Salt Lake is not used for drinking water.
- At the Hayden facility, releases to the Gila River located 80 meters away could occur due to seepage through ground water. There is a potential for seepage from the impoundment to ground water in the event of a liner failure, as discussed in the section above. Contamination of the river could threaten aquatic life in the river, and restrict its potential use. Risks to current human populations via surface water contamination are not expected, however, because there are no known consumptive uses of the river within 24 km downgradient of the facility.

Air Release, Transport, and Exposure Potential

Because all of the constituents of potential concern in the calcium sulfate sludge are nonvolatile, the contaminants can be released to air only in the form of windblown dust particles. As presented above, only arsenic and cadmium are present in the sludge in concentrations that exceed the risk screening criteria for inhalation. Although the sludge consists of very fine particles (0.02 micrometers or less in diameter), which are highly susceptible to wind erosion, the surface of the sludge dries to form a surface crust that is expected to limit dusting to a large extent.

At the Garfield facility, one of the ponds is allowed to dry while the other pond receives sludge discharges in the form of a slurry. The dried sludge is dredged, stabilized, and disposed in an on-site landfill. During the period that the sludge is dried and exposed to the wind, but before it is dredged and stabilized, wind erosion is possible although limited by the surface crust that forms on the dried sludge. Once stabilized and buried, windblown emissions should not be a problem. If there is any dust blown into the air from dried sludge standing in the impoundment, there is a resident within 100 meters and a total of 10,000 people living within 1.6 km that could be exposed.

At the Hayden facility, the sludge is accumulated at the bottom of an impoundment in a wet or moist form. In this form, airborne releases of dust from the sludge should be negligible. However, the facility is located in a very arid area (Arizona) and the impoundments dry out between wastewater discharges. Dusting from such a dried, inactive impoundment is possible but, again, the surface crust that forms on the sludge after it is dried should help to keep the dust down. If any airborne releases were to occur, the nearest resident (located 90 meters away) as well as the 2,200 people living within 1.6 km could be exposed through the inhalation pathway.

Proximity to Sensitive Environments

As discussed above, the Garfield facility is in a 100-year floodplain, which creates the potential for large episodic releases of the sludge due to flood events. The sludge impoundments at the facility, however, are roughly 3,300 meters from the Great Salt Lake and therefore are unlikely to be affected by floods. The Garfield facility is also in a wetland, which are highly valued because they provide abundant habitat, purify natural waters, and provide flood and storm damage protection, as well as a number of other functions. The Hayden facility is not located in or within a mile of an environment that is vulnerable to contamination or has a high resource value.

Risk Modeling

Although the potential for release and exposure to calcium sulfate sludge contaminants appears to be generally low based on facility settings and management practices, the intrinsic hazard of the sludge composition compelled EPA to rank the sludge as having a relatively high potential to cause human health and environmental risks (compared to other mineral processing wastes studied in this report). Therefore, EPA used the model "Multimedia Soils" (MMSOILS) to estimate the ground-water and surface water risks caused by the management of calcium sulfate sludge at the facilities in Hayden, AZ and Garfield, UT. EPA did not model the risks caused by windblown dust because, as discussed above, the surface of the sludge dries to form a crust that should keep windblown dust to a minimum.

Ground-Water Risks

Using site-specific data with respect to contaminant concentrations, sludge quantities, existing management practices, and hydrogeologic characteristics, EPA modeled potential releases to ground water from the calcium sulfate sludge impoundments at the Hayden and Garfield facilities. The Agency used median contaminant concentration as inputs to the model in order to obtain a "best estimate" of the most likely risks. EPA considered in this analysis the potential releases of arsenic, cadmium, selenium, and mercury, which are the primary constituents of concern through the ground-water pathway based on the preceding analysis of the sludge leachate.

The Agency's ground-water modeling results indicate that all four of these contaminants are likely to remain bound up in the unsaturated zone well beyond the modeling time frame that was considered (200 years). Even though the sludge is generated as a slurry and discharged to impoundments along with liquids, the liquids quickly evaporate in the extremely arid settings of these facilities. After evaporation of the slurry water, the only force available to drive contaminants from the dried sludge to the subsurface is the infiltration of precipitation, which occurs at a very slow rate in these areas of Arizona and Utah. Combining this factor along with the depth to ground water at these sites and the tendency of each contaminant to bind to soil, the Agency predicted that it would take the contaminants at least 350 years to migrate to the water table. Therefore, the predicted risks associated with the release of these contaminants to the subsurface are effectively zero within the 200-year modeling horizon.

Surface Water Risks

To evaluate surface water risks, EPA modeled potential releases and impacts at the facility in Hayden, AZ, which presents by far the greatest surface water threat of the two facilities that generate the sludge (the Hayden facility is located only 80 meters from the moderately sized Gila River, while the impoundments at the Garfield facility are located roughly 3,300 meters from the Great Salt Lake). EPA considered in this analysis the annual loading of contaminants to the Gila River via ground-water seepage and erosion of fine particles from the calcium sulfate sludge impoundment, conservatively assuming that the impoundment is filled with sludge and not covered or equipped with stormwater run-off controls -- even though the impoundment is actually equipped with run-off controls. The Agency predicted the surface water concentrations of 12 constituents after they have been fully mixed in the river's flow: aluminum, antimony, arsenic, cadmium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc. For each constituent, the Agency

compared the predicted concentrations to EPA-approved benchmarks for human health protection, drinking water maximum contaminant levels (MCLs), freshwater ambient water quality criteria (AWQCs) for chronic exposures, and guidelines for irrigation and livestock waters recommended by the National Academy of Sciences.

For all but two constituents, the predicted concentrations in the Gila River were at least one order of magnitude below the various criteria, and most constituent concentrations were more than two orders of magnitude below the criteria. The exceptions were arsenic, the only carcinogen of potential concern, and silver. The predicted concentration of arsenic in the river, if ingested over a lifetime, poses a cancer risk of 2×10^{-4} (i.e., the chance of getting cancer would be 2 in 10,000 over a 70-year lifetime). However, this arsenic concentration is approximately an order of magnitude below the MCL. Furthermore, to the best of EPA's knowledge, the Gila River is not currently used for drinking water within 24 km of the Hayden facility, although it conceivably could be used in the future.

The predicted concentration of silver in the Gila River exceeded the AWQC designed to protect aquatic organisms by a factor of almost three. Chronic exposures to this silver concentration could adversely affect any organisms living in the Gila River.

Of the constituents that were modeled, only selenium is recognized as having the potential to biomagnify (concentrate in the tissues of organisms higher in the food chain). Although EPA predicted surface water concentrations of selenium that were more than two orders of magnitude below the AWQC, there is a potential for selenium to biomagnify and cause adverse effects to wildlife at higher trophic levels.¹⁹ Cadmium, selenium, zinc, lead, and to a lesser extent, arsenic may bioaccumulate in the tissue of freshwater fish that may be ingested by humans. Using assumptions about fish ingestion rates,²⁰ the Agency estimates that long-term ingestion of fish caught from the Gila River could pose a cancer risk of 3×10^{-6} . Fish ingestion would not result in a chemical dose that exceeds a noncancer effect threshold.

EPA believes these are reasonably conservative, upper-bound estimates of the surface water risks at the Hayden Facility. As discussed above, the impoundment at this facility is actually equipped with stormwater run-off controls and, depending on the efficiency of these controls, the concentrations of contaminants in the Gila River should be lower than predicted.

6.3.4 Damage Cases

EPA reviewed State and EPA regional files in an effort to document the performance of waste management practices for slag, slag tailings, and calcium sulfate sludge from the treatment of wastewater from primary copper processing, at the 10 active facilities and at eight inactive (at least with respect to primary copper processing) facilities. The inactive facilities included: Cox Creek Refining in Baltimore, MD; ASARCO in Tacoma, Washington; ASARCO in Corpus Christi, Texas; Anaconda in Anaconda, Montana; AJO in New Cornelia, Arizona; South Wire Co. in Carrolton, Georgia; Highland Boy Smelter in Near Salt Lake, Utah; and Midvale Slag in Midvale, Utah.

The file reviews were combined with interviews with State and EPA regional regulatory staff. Through these case studies, EPA found no documented environmental damages attributable to slag tailings or calcium sulfate sludge management. EPA did find documented environmental damages associated with copper slag at four facilities: ASARCO in Tacoma; ASARCO in El Paso; Anaconda in Anaconda; and Midvale Slag in Midvale.

ASARCO, Tacoma, Washington (Commencement Bay, Puget Sound)

ASARCO's smelter is located in the Nearshore area close to Ruston. The plant, operational from the late 1800's until March 1985, generated copper slag that has been deposited along the shoreline near the plant and has been used as fill, riprap, and ballast material in the Tideflats area of Commencement Bay. The slag has also been used to produce building insulation and commercial sandblasting material, which has been used in the Nearshore/Tideflats area.²¹

¹⁹ The AWQC for selenium does not necessarily protect against biomagnification.

²⁰ For the purpose of this screening-level analysis, EPA assumed that a 70-kg individual ingests 6.5 grams of fish from the Gila River every day of the year for 70 years. This is a typical daily fish intake averaged over a year (EPA, Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), EPA/540/1-89/002, December 1989).

²¹ Tetra Tech, Inc., 1985, Summary Report for Commencement Bay Nearshore/Tideflats Remedial Investigation, August, 1985.

Commencement Bay is an embayment of approximately nine square miles in southern Puget Sound, Washington. The bay opens to Puget Sound to the northwest, with the city of Tacoma situated on the south and southeast shores. Residential portions of northeast Tacoma and the Browns Point section of Pierce County occupy the north shore of the bay.

From November 1983 through June 1984, the Washington Department of Ecology Water Quality Investigation Section (WQIS) conducted a remedial investigation to characterize surface run-off from 12 log storage and sorting facilities ("sort yards") in the Tideflats area and contamination of adjacent surface water and sediment in the Blair and Hylebos Waterways. These log sort yards have received ASARCO's slag as ballast material.^{22,23}

According to the WQIS report dated February 27, 1985: "Metals concentrations were measured in run-off from twelve log sort yards on the Tacoma tideflats and in the adjacent surface waters and sediments of Blair and Hylebos Waterways. High concentrations of arsenic, zinc, copper, and lead were present in the run-off from ten yards....The combined annual metals loads (pounds/year) to Commencement Bay waterways from all twelve yards were estimated to be: arsenic, 2,500; zinc, 1,100; copper, 510; lead, 310; nickel, 66; antimony, 50; and cadmium, 2. Because it appears surface run-off accounts for only about 40 percent of the rainfall in these sort yards, there is a strong probability that contaminated groundwater may be a substantial additional source of metals flux to the waterways....Peak concentrations of arsenic, zinc, and copper in surface water and sediments in Blair and Hylebos Waterways were recorded in the vicinity of the log sort yards. EPA acute criteria for the protection of saltwater aquatic life were exceeded for zinc and copper in Blair and Hylebos surface waters adjacent to discharges from Murry Pacific yards #1 and #2 as well as the Wasser/Winters yard....The use of ASARCO slag for ballast at the log sort yards is, in all probability, the major source of elevated metals concentrations seen in log sort yard run-off, nearshore surface waters, and sediments."²⁴

WQIS did a comparison of metals concentrations in ASARCO slag and WQIS data on log sort yard run-off, nearshore surface water, and sediment. The WQIS report concluded that the major source of elevated metal concentrations seen in the log sort yard run-off, and adjacent surface waters and sediment, was the ASARCO slag previously used by the yards for ballast.²⁵

During 1986 and 1987 EPA conducted site inspections of four log sort yards and one wood waste landfill (B&L Landfill) in the Nearshore/Tideflats. The inspection included the installation of 23 monitoring wells, and collection of 25 soil samples and 68 ground-water samples. Soil samples taken at log sort yards indicated arsenic content ranging from 5.5 to 8.2 mg/kg, copper content ranging from 3.0 to 24 mg/kg, lead ranging from 2.7 to 10 mg/kg, and zinc ranging from 22 to 55 mg/kg. Unfiltered ground-water samples from wells installed at the log sort yards contained arsenic at levels ranging from 0.011 to 0.22 mg/L, copper ranging from 0.018 to 0.696 mg/L, lead ranging from 0.0074 to 0.300 mg/L, and zinc ranging from 0.025 to 0.865 mg/L.²⁶

According to the EPA site inspection report for the Nearshore/Tideflats area, of the 19 ground-water monitoring wells installed in or around the four log sort yards, ground-water samples from 15 of the 19 wells exceeded one or more drinking water standards, maximum contaminant levels (MCLs), or freshwater and marine acute and chronic ambient water quality criteria (WQC) identified for one or more of the four contaminants of concern (arsenic, copper, lead, zinc).²⁷

²² Norton, Dale, and Johnson, Art, 1985a, Washington Department of Ecology, Water Quality Investigation Section, Memo to Jim Krull, Re: Completion Report on Water Quality Investigation Section Project for the Commencement Bay Nearshore/Tideflats Remedial Investigation: Metals Concentrations in Water, Sediment, and Fish Tissue Samples from Hylebos Creek Drainage, August, 1983 - September 1984, January 25.

²³ Norton, Dale, and Johnson, Art, 1985b, Washington Department of Ecology, Water Quality Investigation Section, Memo to Jim Krull, Re: Completion Report on Water Quality Investigation Section Project for the Commencement Bay Nearshore/Tideflats Remedial Investigation: Assessment of Log Sort Yards as Metals Sources to Commencement Bay Waterways, November 1983 - June 1984, February 27.

²⁴ Ibid.

²⁵ Ibid.

²⁶ Ecology and Environment, Inc., 1987, Site Inspection Report: Commencement Bay Nearshore/Tideflats, Tacoma, Washington, Vols. I and II, November.

²⁷ Ibid.

Anaconda Smelter Site, Anaconda, Montana

The Anaconda facility is located at the southern end of the Deer Lodge Valley, approximately 25 miles northwest of Butte. From 1884 to 1980, ore from mines near Butte, Montana was transported and processed at various locations on the Anaconda site. In 1902, facilities were developed at the present smelter site on the south side of Deer Lodge Valley about one-half mile east of the town of Anaconda. Ore was mechanically concentrated, roasted, and smelted in reverberatory furnaces to produce copper matte and slag (as a waste product). The slag was cooled and granulated with the addition of water and the resulting slurry was transported to the waste pile through a system of flumes.²⁸ The facility is one of four Superfund sites in the Upper Clark Fork Basin area of southwestern Montana. Among the operable units identified for cleanup is the slag.²⁹

Although the facility has not operated since 1980, ore beneficiation and processing wastes, including about 142 million cubic meters (185 million cubic yards) of tailings, about 21 million cubic meters of furnace slags, and about 190,000 cubic meters of flue dust, are contained within an area of more than 2400 hectares (6,000 acres) at the site.³⁰ These wastes contain elevated concentrations of heavy metals, such as copper (3,140 - 9,760 mg/kg), cadmium (4.4 - 44 mg/kg), arsenic (498 - 3,190 mg/kg), lead (364 - 4,310 mg/kg), and zinc (8,380 - 36,300 mg/kg).³¹

Anaconda's smelter slag has been used by the Montana Department of Highways for sanding roads, some of which parallel the shore of Georgetown Lake. In a November 1982 EPA report, distributed to the Technical Advisory Committee of the Clean Lakes Project in Anaconda, Montana, it was recommended that use of the smelter slag for road sanding be at least partially terminated based on the consistent occurrence of mercury in water samples that had been exposed to slag, the presence of cadmium above background levels in lake water and downstream samples, and the fact that zinc and copper are released by slag under conditions obtainable in the aquatic environment in Georgetown Lake. The report states that no danger to human health existed through contamination of the Georgetown Lake ecosystem by slag or slag leachates from road sanding operations, but that the potential existed that fish were being "negatively affected in their reproduction."³²

A 1983 report by the U.S. Department of Health and Human Services noted that hazards from closed mining operations include potential airborne exposures from dust clouds containing heavy metals from tailings ponds or slag piles. Based on findings in this study, the report recommended that public access to the Anaconda site be terminated, that the waste slag not be used for any commercial purposes, and that further testing should be conducted.³³

²⁸ Anaconda. 1985. Granulated Slag Pile, Draft, Stage I Remedial Investigation Report.

²⁹ U.S. Environmental Protection Agency, Region VIII, 1990. Letter from C. Coleman to K. McCarthy, ICF Incorporated, Re: Anaconda Smelter. May.

³⁰ U.S. Environmental Protection Agency and Montana Department of Health and Environmental Sciences. 1988. Clark Fork Superfund - Master Plan.

³¹ Clement Associates, Inc. 1985. Letter from M.C. Lowe to M. Bishop, Region VIII EPA, Re: Response to Request by County to Use Granulated Slag on Roads.

³² U.S. Environmental Protection Agency. 1982. Memorandum from M. Kahoe to Technical Advisory Committee Member.

³³ U.S. Department of Health and Human Services. 1983. Memorandum from Chief, Superfund Implementation Group to E. Skowronski, EPA Region 7, 8.

Because of the results of these findings, other agencies have reached similar conclusions. In addition to the U.S. Department of Health and Human Services, the U.S. EPA and the Montana Department of Health and Environmental Sciences have all recommended that the Anaconda smelter slag no longer be used for road sanding activities.^{34,35,36}

³⁴ Ibid.

³⁵ Camp Dresser & McKee Inc. 1985. Memorandum from J. Ericson to M. Bishop, EPA, Re: Response to County's Request to Use Granulated Slag for Winter Road and Sanding Operations.

³⁶ Montana Department of Health and Environmental Sciences. 1984. Letter from J.J. Drynan to G. Wicks, Director, Department of Highways, Helena, metric tons.

A 1985 Draft Stage I Remedial Investigation Report, prepared by Anaconda, noted that leachate samples from the slag pile contained cadmium at less than 0.004 to 0.03 mg/L, lead at less than 0.003 to 0.025 mg/L, and copper at 0.128 to 11.6 mg/L. The maximum leachate concentrations from these samples exceeded drinking water MCLs for cadmium (MCL = 0.01 mg/L), and copper (MCL = 1.0 mg/L). In addition, the ambient water quality criteria (AWQC) for copper (0.012 mg/L) is exceeded by almost 1,000 times, the AWQC for cadmium (0.0011 mg/L) is exceeded by almost 30 times,³⁷ and the ambient water quality criteria for lead (0.01 mg/L) is exceeded by 25 times.³⁸ Although the use of Anaconda's slag for road sanding has been terminated, the slag material continues to be sold commercially as a sand blasting material. However, a worker at the sandblasting facility has formally complained of skin and throat irritation.³⁸

Midvale Slag Site, Midvale, Utah

The Midvale Slag site is a parcel of land encompassing approximately 330 acres located immediately west of the city of Midvale, which is twelve miles south of Salt Lake City, Utah. Land use within the three mile radius of the site is primarily for agricultural, residential, and transportation purposes. The site is bounded on the west by the Jordan River, with agricultural lands immediately across the river. Residential areas border the north and east sides of the site. Approximately 33,700 individuals live within three miles of the site. EPA proposed the site for the Superfund National Priority List in 1986 (see 51 FR 21099, 21106, June 10, 1986.)

Ground water occurs beneath the site in both a shallow unconfined aquifer system, and a deep confined aquifer system. Ground water from the shallow unconfined aquifer system is used by approximately 500 residents (for domestic use that may not include drinking) and is used to irrigate approximately 24 hectares (60 acres) of agricultural land. Water from the deep confined aquifer is used as the primary source of water for many of the communities in the Salt Lake Valley. Normal annual precipitation at the site is approximately 36 cm (14 inches).

Although the first smelter was constructed at the Midvale Slag site in 1871, most of the smelting activity occurred between 1906 and 1958 when the United States Smelting, Refining, and Mining Company owned the property. Beginning in 1905, the smelter processed copper and lead concentrates from the United States Smelting, Refining, and Mining Company Mill, and from custom shippers. Remnants of the smelter activity include a large slag pile, approximately 40 hectares (100 acres) in size.

In 1958, operations at the smelter ceased, and shortly thereafter the smelter facilities were dismantled. The site was purchased in 1964 by Valley Materials Corporation (VMC), which recovers the slag material for use as road and railroad bed construction material, and as a sandblasting abrasive for industrial and commercial use.

A 1986 hydrogeochemical site characterization study, conducted for VMC, showed that contamination of the shallow (unconfined) aquifer has occurred. Dissolved arsenic, cadmium, and mercury were all detected at levels exceeding MCLs.³⁹ In discussing the cause of this contamination, the slag was not mentioned as a source; however, given the composition of the slag, the extent of the site covered with slag, and the proximity of the slag to other wastes, it seems likely that the slag is contributing to the contamination to some degree.⁴⁰ Recent hydrogeological studies at the site indicate that there is interconnection between the deep confined aquifer and shallow portions of the valley aquifer under the site.⁴¹

³⁷ Anaconda. 1985. Granulated Slag Pile, Draft, Stage I Remedial Investigation Report.

³⁸ U.S. Environmental Protection Agency, Region VIII. Letter from C. Coleman to K. McCarthy, ICF Incorporated, Re: Anaconda Smelter. May.

³⁹ Earthfax Engineering, 1986. Hydrogeochemical Characterization of the Valley Chemicals Corporation Site, Midvale, Utah. Prepared for Valley Materials Corporation. August.

⁴⁰ Earthfax Engineering, 1986. Leaching Potential of Slag and Slag-Based Airblasting Abrasives at the Valley Chemicals Corporation site, Midvale, Utah. Prepared for Valley Materials Corporation. June.

⁴¹ Camp, Dresser, & McKee, 1990. Hydrogeologic information provided during the Sharon Steel Superfund Site Remedial Investigation and Feasibility Study on Operating Unit 1; Ground Water. U.S. Environmental Protection Agency Administrative Record on the Sharon Steel/Midvale Tailings site.

In 1987, EPA completed a "Final Preliminary Level I Endangerment Assessment" of the Midvale Slag site. As discussed in the report, various smelter wastes have been deposited on site, including slag, dross, and baghouse dust, and all contain high concentrations of heavy metals. According to the report, the slag contains up to 340 ppm arsenic, 45 ppm cadmium, 2,380 ppm copper, 9,410 ppm lead, 36 ppm silver, and 58,500 ppm zinc. As stated in the report: "None of the waste sources are adequately secured and releases have occurred through air and groundwater pathways. In addition, direct contact with these waste sources is very likely due to the extensive earth moving and industrial vehicle activity at the site."⁴²

As stated in the report: "... current studies indicate that several metals are present in ground water, air (by indirect inference), and soil in the vicinity of the Midvale Slag site at concentrations that may endanger human health and the environment. Access to the site is currently not restricted and a commercial slag operation exists on-site, resulting in extensive earth moving and industrial vehicle activity on site. Fine grained waste source material may be inhaled, ingested, deposited as household dust, or deposited on nearby soils. Contaminants from the site also appear to be leaching into the ground-water system."⁴³

In presenting a risk and impact evaluation, the report states: "Metal contamination from the Midvale Slag site presents a potential endangerment to human health and the environment due to actual and potential exposure and toxicity." All residents adjacent to the Midvale Slag site, as well as on-site workers, are potentially subjected to arsenic, cadmium, chromium, lead, and silver exposure via inhalation of contaminated dust. Consumption of crops or garden vegetables grown in contaminated soils may also increase human exposure to these contaminants.⁴⁴ The report also notes that children from ages six to 16 may play or ride bicycles on the waste piles, increasing the risk of ingestion.

The report concludes that "over two million tons of accumulated, unconsolidated slag waste, smelter waste, dross, and baghouse dust at the Midvale Slag site have caused metals contamination on-site and, probably, off-site."⁴⁵

ASARCO, El Paso, Texas

ASARCO's El Paso Plant is located in El Paso, Texas, between Interstate Highway 10 and the Rio Grande River. ASARCO's smelting plant is used for the recovery of zinc, copper, and lead, for production of the principal products, copper anodes, lead bullion, and zinc oxide. ASARCO has operated the El Paso facility since 1883.

Waste smelter slag has historically been deposited on-site. Many of the present structures are built on old waste slag deposits. Slag from the zinc fuming furnace and copper reverb process is stored on-site and removed by a contractor, who crushes it and sells the material for railroad bedding or sandblasting abrasives. Lead slag is being stored on-site until it becomes economically viable to recycle and refine this material for zinc recovery.⁴⁶

Waste piles have been built on slag deposits of unknown permeability. In general, the waste piles have received smelting slag from the zinc, copper, and lead processes, fire assay crucibles, used kiln brick, iron scrap, and pond dredgings.⁴⁷

Samples from stormwater run-off taken in 1981 and 1982 show that primary and secondary drinking water levels were exceeded for arsenic, cadmium, chromium, copper, lead, manganese, mercury, silver, and zinc. Samples from the southern edge of the slag deposits that were taken in July 1981, and September and December, 1982 show ranges of total concentrations of metals as follows: arsenic, 0.84 to 11.6 mg/L; cadmium, 2.05 - 12.0 mg/L; chromium, 0.04 - 0.31 mg/L;

⁴² EPA Region VIII. September, 1987. Preliminary Level I Endangerment Assessment, Midvale Slag Site. Document No.: 347-ES1-RT-FBBL, as a part of "Performance of Remedial Response Activities at Uncontrolled Hazardous Waste Sites.

⁴³ Ibid.

⁴⁴ Ibid.

⁴⁵ Ibid.

⁴⁶ Engineering Science, Inc. 1984. RCRA 3012 Site Inspection Comments.

⁴⁷ U.S. Environmental Protection Agency, Region VI. No date. Surface Impoundments Site Inspection Report for Holding Pond and Storage Facilities Site Inspection Report.

copper, 16 - 240 mg/L; lead, 28 - 220 mg/L; manganese, 2.3 - 12.0 mg/L; mercury, 0.046 - 0.160 mg/L; and zinc, 21 - 102 mg/L. Silver was detected at 1.28 mg/L. In addition, EP toxicity criteria were exceeded for lead, cadmium, and arsenic. The Texas Department of Water Resources concluded that ASARCO was in violation of Texas regulations prohibiting discharge of hazardous metals to inland waters (TDWR Permanent Rules 156.19.002).⁴⁸

An Industrial Solid Waste Compliance Monitoring Inspection, conducted in 1985 by the Texas Department of Water Resources, noted that stormwaters from the slag landfills and from the plant, which has received much slag fill, have high levels of heavy metals and have discharged into the American Canal and the Rio Grande River.⁴⁹

In 1986, a Solid Waste Compliance Monitoring Inspection Report was completed by the Texas Water Commission. When compared to concentrations upstream and downstream of the facility, elevated concentrations of arsenic, lead, cadmium, and copper in Rio Grande sediments near the ASARCO facility waste slag were found. For example, lead was detected at 7.0 mg/L upstream, 62 mg/L at the ASARCO facility, and 24 mg/L downstream.⁵⁰

According to the Texas Water Commission, the primary problems at this site have evolved from surface run-off from slag piles and unlined settling ponds. In June 1987, The TWC Superfund Unit determined that improvements at the facility, e.g., lining the ponds and diverting surface run-off to a central retention area for sampling before discharge, had resulted in the company achieving compliance with the Texas Water Code.⁵¹

6.3.5 Findings Concerning the Hazards of Primary Copper Processing Special Wastes

Copper Slag

Copper slag constituents that pose the greatest potential threat to human health and environment include arsenic, copper, lead, molybdenum, and cadmium, although there are nine other contaminants that exceed the conservative risk screening criteria. Cadmium and lead measured in EP leach tests exceeded the EP toxicity regulatory levels in one out of roughly 70 samples. However, when analyzed using the SPLP test, neither of these constituents failed the EP toxicity criteria.

Based on an examination of the characteristics of each site and predictive modeling, copper slag appears to pose a low risk at most of the active copper facilities. Almost all of these facilities are located in areas with generally low-risk environmental and exposure characteristics (e.g., very low precipitation and net recharge, large depths to ground water, minimal use of nearby surface and ground-water resources, and great distances to potentially exposed populations). A possible exception is the facility in White Pine, MI. Using the conditions at White Pine as a conservative model, the Agency predicts low risks associated with potential releases of slag contaminants to ground water and air, including cancer risks that are below 1×10^{-6} and contaminant concentrations at possible exposure points that are orders of magnitude below hazard criteria. Erosion of contaminants into nearby surface waters, however, could cause greater impacts. The Agency predicts that, if not controlled, erosion from a slag pile could result in annual average surface water concentrations of lead, iron, and molybdenum that exceed MCLs or irrigation guidelines by a narrow margin (a factor of 2 or less), as well as copper concentrations that exceed the AWQC by as much as a factor of 65. Contamination of this magnitude, however, should not actually occur at the White Pine Facility because the slag dump at that site is equipped with stormwater run-on/run-off controls. Similarly, significant surface water contamination is not expected at the other sites because the nearest surface waters are farther away and have a greater assimilative capacity than the conservative conditions that were modeled.

⁴⁸ U.S. Environmental Protection Agency. August 27, 1984. Potential Hazardous Waste Site Tentative Disposition.

⁴⁹ Texas Department of Water Resources. 1985. Industrial Solid Waste Compliance Monitoring Inspection Report.

⁵⁰ Texas Water Commission. April 26, 1986. Solid Waste Compliance Monitoring Inspection Report.

⁵¹ U.S. Environmental Protection Agency, Region VI. June 2, 1987. Record of Communication from Christy Smith, Head, TWC Superfund Unit to David Gonzalez, Re: ASARCO, Inc.

The general lack of documented cases of damage caused by copper slag at the active copper facilities confirms that the slag at these facilities often poses a low risk. The only damage case for an active site involved storm water run-off from slag piles at the El Paso facility and subsequent surface water contamination, as predicted to be possible by the Agency's modeling. The El Paso facility has since installed a run-off retention system. The other damage cases are for inactive facilities and demonstrate the potential for damage under mismanagement scenarios that generally do not represent the industry norm.

Copper Slag Tailings

Compared with the other copper wastes, copper slag tailings contain a smaller number of contaminants in generally lower concentrations. The greatest potential for hazard appears to be associated with the tailings' arsenic concentrations. Based on professional judgment and available sampling results, EPA believes that the tailings do not exhibit any of the characteristics of a hazardous waste.

Based on the Agency's review of existing management practices and release/exposure conditions, as well as the lack of documented cases of damage caused by copper slag tailings, the overall hazard associated with the tailings appears to be low. Although the tailings are generated as a slurry and co-managed with liquids that could serve as a leaching medium, the contaminant concentrations in the leachate are generally low. Furthermore, ground water at the three facilities that actively generate and manage the tailings is either very deep (and thus somewhat protected) or not used within a mile. It is possible, however, that the ground water could be used sometime in the future. Except for the White Pine facility, where there is a moderate potential for tailings contaminants to migrate into surface water, the potential for the tailings to cause significant surface water contamination appears very remote. Airborne dusting from the tailings piles can and does occasionally occur. Windblown dust from the piles should be studied further and, if needed, controlled to prevent significant inhalation exposures to arsenic and chromium.

Calcium Sulfate Sludge

Although calcium sulfate sludge contains as many as 12 contaminants that could pose a risk under worst-case exposure conditions, the constituents that pose the greatest potential threat to human health and the environment are arsenic, cadmium, lead, and selenium. Concentrations of arsenic and selenium in the sludge leachate, as measured using the EP leach test, exceeded the EP toxicity regulatory levels in seven out of seven samples, while cadmium exceeded the regulatory level in six of seven samples. However, using the SPLP test, no contaminants exceeded the EP toxicity regulatory levels.

Based on a review of existing management practices and facility settings, as well as predictive modeling results, EPA believes that the hazards associated with calcium sulfate sludge are generally low at the two facilities where it is currently generated. Both facilities that actively generate and manage the sludge are located in very arid locations (Hayden, AZ and Garfield, UT) where there is very little precipitation and recharge to ground water. Even the liquids used to slurry the sludge into the impoundments are expected to quickly evaporate, rather than seep into the ground. Considering this lack of water to carry sludge contaminants to the subsurface, along with the depths to ground water and the tendency of the sludge contaminants to bind to soil, EPA predicts that it would take more than 200 years for contaminants to migrate from the sludge into ground water. However, there does appear to be a slight potential for surface water contamination caused by sludge management practices at one of the sites. If the impoundment at Hayden is conservatively assumed to be filled with sludge and not equipped with a cover or run-off control system, the Agency predicts that erosion from the impoundment could cause arsenic and silver concentrations in the nearby Gila River that exceed health and ecological protection criteria. However, because the impoundment at Hayden is in fact equipped with run-off controls, surface water contamination of this magnitude is not actually expected. The potential for significant releases of windblown dust from the sludge appears very remote, because the surface of the sludge dries to form a crust that is resistant to wind erosion.

No cases of documented damage caused by the sludge were discovered by EPA. This finding supports the conclusion that as currently managed the sludge poses a generally low hazard.

The intrinsic hazard of the waste, however, is high. Several other primary copper facilities may generate the sludge in the future, especially if the waste remains excluded from RCRA Subtitle C regulations. As discussed above with respect to slag and slag tailings, the environmental settings of some of these other facilities is such that risks

associated with calcium sulfate sludge generated at these facilities could be higher than at the two facilities where it is currently generated, assuming that the additional facilities used management practices similar to those currently in use. Similarly, off-site use or disposal could result in higher risks than those predicted for the facilities where the waste is currently generated.

6.4 Existing Federal and State Waste Management Controls

6.4.1 Federal Regulation

Under the Clean Water Act, EPA has the responsibility for setting "effluent limitations," based on the performance capability of treatment technologies. These "technology based limitations," which provide the basis for minimum requirements of NPDES permits, must be established for various classes of industrial discharges, which include a number of ore and mineral processing categories.

Permits for mineral processing facilities may require compliance with effluent guidelines based on best practicable control technology currently available (BPT) or best available technology economically achievable (BAT). BPT and BAT requirements for primary copper smelting specify that there shall be no discharge of process wastewater pollutants to navigable waters (40 CFR 421.43 and 421.44).⁵²

A number of States with primary copper smelter facilities do not have EPA-approved NPDES programs. In New Mexico, Region VI personnel have stated that existing Federal guidelines are applied for discharges from primary copper smelters. However, the Region may adopt State water quality criteria or any other standards that are more stringent than Federal guidelines as required by Sections 402 and 510 of the CWA. Similarly, the State of Arizona has no approved NPDES program; therefore, Federal requirements would be applicable. Region IX may, however, adopt State water quality standards more stringent than Federal guidelines.

Limitations on air emissions, National Emission Standard for Hazardous Air Pollutants (NESHAP), have been established by EPA under the Clean Air Act (40 CFR 61.12) for emissions of inorganic arsenic from primary copper smelter convertors. The standards require operators to meet certain design, equipment, work practice, and operational requirements in order to achieve emission reductions.

The Cyprus Miami Mining Corporation Copper Smelter in Claypool, Arizona is located on Federal land, in a National Forest. This facility is subject to the regulations set forth by the U.S. Forest Service. National Forest System lands are regulated by the U.S. Department of Agriculture's Forest Service. The regulations governing the use of the surface of National Forest Service lands (36 CFR 228 Subpart A) are intended to "minimize adverse environmental impacts...." The regulations require that operators file a "notice of intent to operate." If deemed necessary, the operator may be required to submit a proposed plan of operations in order to ensure minimal adverse environmental impact.

The National Environmental Policy Act (NEPA) may also be applicable to this facility. NEPA may require that an Environmental Impact Statement (EIS), which establishes the framework by which EPA and the Council on Environmental Quality may impose environmental protection requirements (40 CFR Parts 1500-1508), be prepared for any ore processing activities on Federal lands.

6.4.2 State Regulation

One or more of the three special wastes from primary copper processing (slag, slag tailings, and calcium sulfate sludge) are generated at 10 facilities located in five states, including Arizona (three facilities), Michigan (one facility), New Mexico (two facilities), Texas (three facilities), and Utah (one facility). All five of these states exempt the special primary copper processing wastes generated by the facilities from regulation as hazardous waste. Of these five states, only Michigan was not selected for detailed study for the purposes of this report (see Chapter 2 for a discussion of the methodology used for selecting study states). Copper slag is generated at facilities located in all four of the study states,

⁵² This limitation includes a provision, however, that an impoundment designed to contain the 10-year, 24-hour rainfall event may discharge that volume of process wastewater which is equivalent to the volume of precipitation that falls within the impoundment in excess of that attributable to the 10-year, 24-hour rainfall event, when such event occurs.

while slag tailings and calcium sulfate sludge are generated at facilities located in Arizona and Utah only. Based on the location of the nine facilities in the four study states, and the waste streams that those facilities generate, the state regulation of primary copper processing wastes is of principal interest in the States of Arizona, Utah, and Texas.

The three primary copper processing facilities in Arizona generate one or more of this sector's three special wastes. Because Arizona's solid waste regulations classify mineral processing wastes as industrial solid wastes, all three waste streams are subject to these solid waste regulations. According to state officials, however, the state's emphasis in implementing its regulations has been on municipal solid waste landfills; the state has not imposed regulations specifically addressing wastes from mining or mineral processing operations. Arizona also has in place a ground-water discharge permitting program that specifically lists surface impoundments, including holding impoundments, storage settling impoundments, treatment or disposal pits, ponds, lagoons, and mine tailings piles or ponds, as discharging units that must be permitted. Arizona has focused its efforts to date, however, on permitting new facilities. The single facility generating calcium sulfate sludge, thus, does not have a ground-water discharge permit, while the other two facilities have permits for only selected mining and mineral processing waste units. Finally, Arizona regulations adopt federal new and existing source performance standards for primary copper smelting operations, including fugitive dust limitation conditions for tailings piles and ponds.

Utah is the only other state in which all three special wastes from primary copper processing are generated. A single copper processing facility in Utah generates all of these wastes. Utah excludes all of these processing wastes from both its hazardous waste and solid waste regulations. The state does have an approved NPDES program, however, and imposes discharge permit requirements on the tailings impoundment used for disposing slag tailings and other wastes at its one facility. The state also recently enacted new ground-water protection legislation, though it has not yet issued any ground-water discharge permits. Finally, Utah's air regulations specifically regulate sulfur dioxide and visible compounds air emissions at the facility, but address fugitive dust emissions only under general requirements for tailings ponds and piles.

The two facilities in New Mexico, three facilities in Texas, and one facility in Michigan generate copper slag only, though two of the Texas facilities do not generate smelter slag and recycle their converter and anode slag. New Mexico specifically excludes mineral processing wastes from its solid waste regulations. Both EPA and state effluent discharge limitations apply at both New Mexico facilities. Moreover, both facilities have discharge plans for the protection of ground water, though neither of the facilities' plans address slag disposal. Similarly, New Mexico's air regulations require permits for all sources of air contaminants and specify limitations for a variety of mineral processing operations, though copper processing is not mentioned specifically. In contrast to New Mexico, Texas addresses copper slag under its solid waste regulations. Only one of the three facilities in the state, ASARCO's El Paso facility, is subject to the requirements of these regulations and other environmental regulations, however. The state has not addressed the other two facilities because those facilities reuse their slag. Moreover, Texas has required only that the ASARCO plant notify the state of its waste management activities and provide basic waste characterization information; the state has not required a solid waste disposal permit at the facility because ASARCO disposes of its slag on property that is both within 50 miles of the facility and is controlled by the company. Texas surface and ground-water protection criteria and fugitive dust emission controls apply at the ASARCO facility only. Texas has not imposed fugitive dust controls at the ASARCO facility, but has actively implemented its water protection regulations and is currently administering an enforcement order addressing un-permitted releases to the Rio Grande River. Finally, although Michigan was not studied in detail for this report, review of the state's regulations suggest that the copper slag generated at the White Pine facility is exempt from solid waste regulations because it is reused.

In summary, all of the states with primary copper processing facilities exclude the special processing wastes generated at these facilities from their hazardous waste regulations. The states vary in the application of solid waste regulations to these wastes. Both Utah and New Mexico specifically exempt mineral processing wastes from solid waste regulation, while Michigan's regulations contain exemptions for slag that is reused or reprocessed. Although Arizona and Texas classify primary copper processing wastes as solid wastes, neither state has actively regulated the management of these wastes under such authority. In contrast, all of the states appear to address some or all of the copper processing wastes generated within their borders to some extent under state surface water discharge permitting programs, while Arizona and New Mexico have ground-water discharge permit programs and Utah recently enacted ground-water protection legislation that will require permits. Finally, although all of the states appear to have general fugitive dust emission control requirements that could apply to copper processing wastes, the extent to which those requirements are being applied is not clear.

6.5 Waste Management Alternatives and Potential Utilization

6.5.1 Waste Management Alternatives

Waste management alternatives, as discussed here, include both waste disposal alternatives (e.g., landfills and waste piles) and methods of minimizing the amount of waste generated. Waste minimization alternatives include source reduction or recycling that results in either the reduction of total volume or toxicity of the waste. Source reduction is a reduction of waste generation at the source, usually within a process, that can include treatment processes, process modifications, feedstock (raw material) substitution, housekeeping and management practices, and increases in efficiency of machinery and equipment. Source reduction includes any activity that reduces the amount of waste that exits a process. Recycling refers to the use or reuse of a waste as an effective substitute for a commercial product, or as an ingredient or feedstock in an industrial process.

Opportunities for waste minimization through raw materials substitutions are limited in general by the characteristics of the ores that are processed. Selection of source ores, improved beneficiation techniques, or improvements in smelting technology, however, in some cases may lead to reduced slag volumes. Other source reduction opportunities may involve process modifications that increase the efficiency of metal recovery during the smelting operation.

The following discussion describes opportunities for recycling copper smelter slag that are practiced in the U.S. and miscellaneous potential waste minimization practices for all three special wastes generated in primary copper processing.

Recycling Copper Slag

The primary purpose of recycling copper slag is to recover additional copper from the slag. There are six types of primary copper slag generated in the U.S.: converter, anode, reverberatory furnace, electric furnace, flash furnace, and continuous smelter slags. Opportunities for recycling slag exist primarily for the four types of smelter slag because most, if not all, of the converter and anode furnace slag generated at primary copper processing facilities in the U.S. already is recycled to the process -- anode furnace slag to the converter and converter slag to the smelter. There are three primary methods of recycling copper smelter slag used at U.S. facilities. The method used depends upon the type of smelting furnace at the facility.

Description

Recycling of reverberatory furnace slag involves crushing and screening, and a subsequent separation of the minerals in the slag by froth flotation in a concentrator. In this process, the copper is caused to float to the surface with the addition of chemicals called "floaters," and is removed in a foam of air bubbles. Other minerals sink to the bottom, are carried out in the slurry, and are disposed of in tailings ponds. The primary residuals from this process are wastewater (about 50 to 230 metric tons per metric ton of concentrate) and the tailings (about 25 to 50 metric tons per ton of concentrate.)

Electric furnace slag has a lower copper content than reverberatory furnace slag, making it less amenable to recycling using a concentrator. In fact, electric furnace treatment is one method of recycling slag, as discussed below.

Flash furnace and continuous (Noranda) smelter slags are relatively high in copper content. This copper may be reclaimed by electric furnace slag treatment or by slow cooling, crushing, and flotation. Coke is used in an electric furnace to reduce sulfates and metallic copper and reconstitute the copper as a sulfide. The molten copper matte may then be recycled to a converter to produce copper metal. In the flotation process, the molten slag is cooled slowly, and copper forms as either small particles of metallic copper or crystals of copper-iron sulfide. These particles are held in a

matrix of primarily iron silicate. The slag is reclaimed, crushed, and sent to the concentrator. The concentrate is then returned to the smelting process.^{53,54}

Current and Potential Use

Of the three U.S. facilities operating reverberatory furnaces in 1988, one has classified its production statistics as confidential. The two other facilities are the Copper Range Company in White Pine, Michigan, and the Magma Copper Company in San Manuel, Arizona. As noted in Section 6.2.3, the Copper Range facility generated and stored 165,000 metric tons of reverberatory furnace slag in 1988. The Copper Range Company's slag pile has accumulated 1,360,000 metric tons of slag, and the facility retrieved 212,000 metric tons of slag from the pile for recycling to the concentrator in 1988.⁵⁵ The Magma facility also added 309,000 metric tons of reverberatory furnace slag in an on-site slag pile in 1988, but "mined" and recycled 996,000 metric tons of reverberatory furnace slag from the pile.⁵⁶

Electric furnaces were used by two facilities in 1988: the Cyprus Miami Mining Corporation in Claypool, Arizona and the Phelps Dodge Mining Company in Playas, New Mexico. The Cyprus facility generated 310,000 metric tons of electric furnace slag in 1988 and disposed 100 percent of it in a tailings pond. Cyprus did not recycle any slag in 1988.⁵⁷ The Phelps Dodge facility operated an electric furnace to process the slag from its flash furnace operations. Its electric furnace generated 336,000 metric tons of slag in 1988. All of the electric furnace slag was sent to a slag pile for disposal and no slag was recycled.⁵⁸

Production statistics for three of the four U.S. facilities employing flash furnaces are non-confidential. The Phelps Dodge Mining Company facility in Playas, New Mexico, the Chino Mines Company (Phelps Dodge) facility in Hurley, New Mexico, and the Magma Copper Company facility in San Manuel, Arizona all operated flash furnaces in 1988. As noted above, the Phelps Dodge facility in Playas sent all of its flash furnace slag to an electric furnace for processing.⁵⁹ The Chino/Phelps Dodge facility in Hurley generated 363,000 metric tons of slag from its INCO flash furnace in 1988 and recycled none.⁶⁰ The Magma facility replaced its reverberatory furnaces with a single flash furnace in 1988. This flash furnace generated 190,000 metric tons of slag in 1988. Magma reportedly recycles all of its flash furnace slag to the ore concentrator.⁶¹

⁵³ PEDCo Environmental, Inc., *Industrial Process Profiles for Environmental Use, Chapter 29: Primary Copper Industry*, EPA-600/2-80-170, Environmental Protection Technology Series, Industrial Environmental Research Laboratory, ORD, U.S. Environmental Protection Agency, July 1980, p. 49.

⁵⁴ White, Lane, "Copper Recovery from Flash Smelter Slags: Outokumpu Upgrades Sorting of Slags and Flotation of Copper," *Engineering and Mining Journal*, November 1983, pp. 77-81.

⁵⁵ Copper Range Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁵⁶ Magma Copper Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁵⁷ Cyprus Miami Mining Corporation, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁵⁸ Phelps Dodge Mining Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁵⁹ Phelps Dodge Mining Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁶⁰ Chino Mines Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁶¹ Magma Copper Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

Finally, the Kennecott Copper Company in Garfield, Utah generated 395,000 metric tons of slag from its continuous Noranda process. This facility reported recycling all of the slag it generated to the slag concentrator.⁶²

The two copper smelting facilities with confidential production statistics are ASARCO's facilities in El Paso, Texas, and Hayden, Arizona. The El Paso facility temporarily stores its slag in a slag pile and sells it to an on-site third party. The material is then used for railroad fill, ballast, and blasting abrasive.⁶³ The Hayden facility disposes of slag in an on-site slag pile and reprocesses a portion to recover the copper content.⁶⁴

Most facilities operating flash furnaces or continuous smelters recycle their smelter slag to the process. Recycling of reverberatory and electric furnace slags is not as common. There may be potential for increasing the quantity of copper smelter slag that is recycled, but it is not clear that such an increase would be economically feasible or that it would substantially affect the volume or composition of the slag generated.

Factors Relevant to Regulatory Status

The specific effects of slag recycling on volume and composition of copper slag are uncertain. Recycling slags to a concentrator reduces volume and copper content of the slag, but creates slag tailings and associated wastewater. Electric furnace treatment of flash or continuous smelter slag generates a slag with a similar content as reverberatory furnace slag.⁶⁵

Feasibility

It is technically feasible to increase slag recycling at facilities that do not currently recycle 100 percent of their smelter slag, but it is not certain that more recycling would be profitable. The primary factor influencing a facility's decision to recycle smelter slag is the concentration of copper in the slag. Slags with low copper content, such as the electric furnace slags, are likely to be disposed instead of recycled due to the increased costs associated with recycling and the minimal benefits (i.e., small quantities of copper recovered).

Miscellaneous Waste Minimization Practices

Some research has been conducted on removing secondary elements from copper slag. The methods researched are worth noting as potential waste minimization practices.

Copper and Secondary Metals Recovery from Converter Slag

Researchers in India have found that copper converter slag with a magnetite content of approximately 8 percent and a FeO/SiO₂ ratio of about 1.2 could be leached at high temperatures with dilute sulfuric acid to recover most of the copper and about 90 percent of the nickel and cobalt. Slags with a higher magnetite content (15-20 percent) and a greater FeO/SiO₂ ratio (1.3) only allowed 40-60 percent recovery of the secondary metals. Slow-cooling this slag, however, enhanced recovery of contained nickel and cobalt to 90 percent.⁶⁶

Iron Recovery and Glass Fiber Reduction from Slag

⁶² Kennecott Copper Company, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁶³ ASARCO Incorporated-El Paso Plant, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁶⁴ ASARCO Incorporated-Hayden Plant, 1989. Company Response to the "National Survey of Solid Wastes from Mineral Processing Facilities," U.S. EPA.

⁶⁵ PEDCo Environmental, Inc., *op. cit.*, p. 68.

⁶⁶ Das, R.P., S. Anand, K. Sarveswara Rao, and P.K. Jena, 1987, "Leaching Behavior of Copper Converter Slag Obtained Under Different Cooling Conditions," *Trans. Institution of Mining and Metallurgy (Section C: Mineral Process. Extr. Metallurgy)*, Vol. 96, September, p. C161.

Researchers from U.C.L.A. found that copper slag from ASARCO's Hayden, Arizona facility could be converted into glass fiber and that iron from the slag could be recovered. The researchers melted down a mixture of 90 percent copper slag and 10 percent CaCO_3 in a Harper globar electric heating furnace using graphite and coal powder as reductants. On remelting, the copper slag usually corrodes oxide refractories because of the iron in the slag, but the addition of coal or graphite to the batch lowered the slag's melting temperature and actually reduced the refractory corrosion. Iron was recovered from the slag by the reduction of the oxide through the ferrous state to the metallic state. Glass was then cast and glass fibers were drawn from the melt.⁶⁷

Minimization of Slag Tailings and Calcium Sulfate Sludge

EPA did not find any information in the literature reviewed concerning minimization of copper slag tailings or calcium sulfate sludge generated by primary copper processing facilities. Copper slag tailings are generated when copper slag is recycled to the concentrator; therefore, the copper content of the tailings could potentially be reduced if a more effective method of concentration were developed. The quantity and composition of both slag tailings and calcium sulfate sludge could be altered if a feasible method of recovering metals (e.g., lead, zinc) were devised for these two special wastes.

Disposal Alternatives

None of the primary copper processing facilities send their special wastes off-site for disposal. While it is conceivable that some, or even all, of the copper processors could do so, the cost of transporting large volumes of copper slag, slag tailings, or calcium sulfate sludge and the rising cost of commercial landfill capacity make it unlikely that copper processors would utilize off-site disposal capacity if on-site capacity is available and the regulatory environment does not change. Situations that could increase the likelihood of off-site disposal are the classification of one or more of the special wastes as hazardous wastes, a limited amount of capacity for on-site disposal, and smaller volumes of special wastes generated.

6.5.2 Utilization

Copper slags historically have been utilized in a variety of ways. Though most copper processing facilities currently recycle or dispose of their slag, there are numerous opportunities for utilization. The application that could potentially use the largest quantities of copper slag is use as a highway construction aggregate. Copper slag tailings have also been utilized for construction purposes in the past, but all facilities currently generating tailings dispose of them. The following section analyzes the potential, as identified in the literature, for use of copper slag in highway construction and various other capacities and discusses past uses of copper slag tailings.

Utilization as a Highway Construction Aggregate

Description

Copper slag has been used experimentally in bituminous wearing surfaces (asphalt) and as a seal coat aggregate in highway construction. Copper slag is a hard, dense material which is either granulated (water cooled) or air cooled. Granulated slags generally range from -8 mesh to +100 mesh in diameter and are considered unsuitable for highway construction because of their resistance to compaction. Air cooled slags, which are the most usable as an aggregate, can range in size from +4 mesh to chunks that measure several inches in diameter. Copper slags, particularly air cooled slags, may require additional crushing and/or screening to achieve uniform sizes for particular applications.⁶⁸

⁶⁷ Chung, C.H., T. Minzuno, and J.D. Mackenzie, 1978, "Iron Recovery and Glass Fiber Production from Copper Slag," Proceedings of the Sixth Mineral Waste Utilization Symposium, Chicago, IL, May 2-3, pp. 145-147.

⁶⁸ Collins, R.J. and R.H. Miller, 1976, *op.cit.*, pp. 111-112, 170.

Current and Potential Use

In the past, copper slag has been used as an aggregate in asphalt and seal coats in Arizona and Utah, states which are among the top generators of copper slag. When used as an aggregate in asphalt, the copper slag performed well and was shown to have desirable anti-skid and wear resistant properties, but these pavements have a high cost associated with them due to the heavy weight (and associated transportation costs) of the aggregate. Therefore, the Utah Department of Highways concluded that the most economical use of copper slag is as a seal coat aggregate. One problem associated with surface mixtures incorporating copper slag is that the aggregate particles have a tendency to become dislodged by traffic, posing the possibility of damaging windshields.⁶⁹

The Testing and Research Division of the Michigan State Highway and Transportation Commission investigated copper reverberatory slag from the White Pine smelter in Michigan for its suitability as an aggregate in highway construction. A number of evaluative tests were performed and the material was found to be suitable as aggregate for all types of highway construction with the exception of aggregate for portland cement concrete.⁷⁰

Access to Markets

It is important that a waste being used as an aggregate be located as close as possible to its market in order to keep transportation costs low. Wastes located within 50 to 100 miles of major metropolitan areas or aggregate shortage areas are considered as being near potential markets.⁷¹ The Cyprus facility in Claypool, Arizona is located 70 miles from Phoenix, Arizona and the Magma facility located in San Manuel, Arizona is located 30 miles from Tucson, Arizona. Also, there is an aggregate shortage located in Northeast Arizona, Southeast Utah, and Northwest New Mexico in which the copper slag from the Arizona, Utah, and New Mexico facilities could be utilized. The Copper Range facility in White Pine, Michigan does not foresee an opportunity for utilization of its slag because of the distance from the facility to potential markets for the slag and high transportation costs, especially since there is no railhead located at the facility.

Feasibility

The major factor in determining the technical feasibility of using copper slag as an aggregate for highway construction is the mechanical properties of the slag. The economic feasibility of using copper slag as an aggregate will depend on the selling price of the slag and retrieval, processing, and transportation costs associated with a particular use in a particular area.

Miscellaneous Uses

Several examples of copper slag and copper slag tailings utilization are cited in the literature, but very few details are provided other than the fact that it has been utilized in some capacity. Given the limited availability of information, a brief discussion of these miscellaneous utilizations is provided below.

Other Construction Materials

Studies have indicated that copper slag has potential use as portland cement replacement in concrete. Mortars incorporating air cooled or quenched slag ground to 5000 cm²/g exhibit compressive strengths that suggest the possibility of their use for structural concrete, but the costs associated with grinding might not justify this use.⁷² Also,

⁶⁹ *Ibid.*, pp. 114, 166, 170.

⁷⁰ Collins, R.J. and R.H. Miller, 1977, Availability of Mining Wastes and Their Potential for Use as Highway Material - Executive Summary, FHWA-RD-78-28, prepared for Federal Highway Administration, September, p. 21.

⁷¹ *Ibid.*, p. 239.

⁷² Douglas, Esther and Paul R. Mainwaring, 1985, "Hydration and Pozzolanic Activity of Nonferrous Slags," American Ceramic Society Bulletin, Vol. 64, No. 5, p. 706.

copper slag can be used as a source of iron in the manufacturing of portland cement,⁷³ (as distinct from use as aggregate in portland cement concrete).

There are a number of other uses of copper slag in construction materials. Granulated copper slag was used during the reconstruction of a portion of the New Jersey Turnpike as an embankment material.⁷⁴ Copper slag has also been used for road cinderling, and as granules for roof shingles. The Copper Range Company in Michigan has used a very small portion (less than 1 percent) of its copper slag locally for driveways, as pipe bedding, and in road beds, when mixed with a sufficient quantity of road rock. Copper slag has been found to have very good drainage characteristics and would be well suited for drainfield construction.⁷⁵

Road or Railroad Ballast

Sized copper slag is an excellent material for use as road or railroad ballast because of its high natural angle of repose and its ability to maintain slopes. For example, copper slag from the Southwest was used in construction of a large portion of the Southern Pacific roadbed from New Orleans to San Francisco.⁷⁶

Mineral Wool Insulation

The Copper Range Company in White Pine, Michigan shipped 38,486 metric tons of copper slag between November 1976 and December 1977 to mineral wool manufacturers. In mineral wool manufacturing, sized copper slag is mixed with other materials to adjust the overall composition of feed to the furnace. The slag mixture is melted with coke in a cupola furnace, and the molten stream from the furnace is spun into a mineral wool.⁷⁷ Copper slag was used in mineral wool production extensively in the past, but has largely been replaced as an input material by steel and iron slags due to the air pollution concerns associated with arsenic and hydrogen sulfide residuals in the copper slag.⁷⁸

Application as an Abradant

Granulated copper slag is used as an abradant in abrasive machining. Other potential uses of copper slag grains are as grit in abrasive blasting, in abrasive tools bonded with low melting ceramic binders, in elastic polyurethane bonded abrasive tools, and in abrasive compounds. It has been discovered that heat treatment enhances the strength of copper slag grains, consequently increasing its potential use in abradants.⁷⁹

Utilization of Copper Slag Tailings

Copper slag tailings and ore tailings may be co-generated by a concentrator or mixed for disposal if there are separate slag and ore concentrators at the facility. References in the literature to the use of copper tailings do not clearly state whether the past uses of tailings applied to only ore tailings, only slag tailings, or both. Presumably, the mechanical properties of both types of tailings will be similar and they could be used individually or in combination for each application.

⁷³ Collins, Robert J., 1978, "Construction Industry Efforts to Utilize Mining and Metallurgical Wastes," Proceedings of the Sixth Mineral Waste Utilization Symposium, Chicago, IL, May 2-3, p. 141.

⁷⁴ Ibid.

⁷⁵ Snyder, Houston L., 1990, Director of Safety and Environmental Affairs, Copper Range Company, White Pine, Michigan, personal communication, April 9.

⁷⁶ Bingham, Edward R., 1968, "Waste Utilization in the Copper Industry," Proceedings of the First Mineral Waste Utilization Symposium, Chicago, IL, March 27-28, p. 75.

⁷⁷ Clarkson, J.F., R.H. Johnson, E. Siegal, and W.M. Vlasak, 1978, "Utilization of Smelter Slags at White Pine Copper Division," Proceedings of the Sixth Mineral Waste Utilization Symposium, Chicago, IL, May 2-3, p. 99.

⁷⁸ Brayman, Bill, Vice President, Rockwool Manufacturing Company, Leeds, Alabama, personal communication, April 11, 1990.

⁷⁹ Wozniak, K., 1988, "Cutting Property Assessment of Copper Slag," Metal Finishing, November, p. 37.

Copper tailings were used in both Michigan and Utah as embankment material and in bituminous mixtures. In Michigan, an unspecified quantity was used as embankment and sub-base material for U.S. Route 41 and for other projects as an aggregate in bituminous mixes and as anti-skid material. Between 1972 and 1976, over 5 million metric tons of classified copper tailings from the Kennecott facility were used in the construction of highway embankments throughout the State. Kennecott constructed a separation facility in 1972 to classify and deposit coarser tailing products which are suitable for use in highway embankments. The largest use of the tailings was 3 million metric tons in the construction of 9.6 kilometers of embankment for Interstate 215. Utah also used tailings as a mineral filler in bituminous mixtures, but the Department of Highways found that this application was not as successful as use in embankment construction.⁸⁰

Conclusions

Although copper slag and slag tailings are commonly either recycled or disposed of in stacks or ponds, there does appear to be some potential for utilization of these materials, particularly in construction applications. There is no indication in the literature reviewed that there are any potential means of utilizing calcium sulfate sludge. If the special wastes were used as construction materials there might, under some circumstances, be concerns regarding potential contaminant release and subsequent environmental degradation. It is unclear whether such non-disposal management alternatives represent a net reduction in the risks posed by these materials as compared to current practices. One major obstacle to more widespread utilization of the special wastes is social acceptability. While utilization of copper slag and slag tailings is likely to be more acceptable to the public than utilization of some of the other special wastes (e.g., lead slag), some opposition to their use in construction materials or in other capacities may be expected.

6.6 Cost and Economic Impacts

Section 8002(p) of RCRA directs EPA to examine the costs of alternative practices for the management of the special wastes considered in this report. EPA has responded to this requirement by evaluating the operational changes that would be implied by compliance with three different regulatory scenarios, as described in Chapter 2. In reviewing and evaluating the Agency's estimates of the cost and economic impacts associated with these changes, it is important to remember what the regulatory scenarios imply, and what assumptions have been made in conducting the analysis.

The focus of the Subtitle C compliance scenario is on the costs of constructing and operating hazardous waste land disposal units. Other important aspects of the Subtitle C system (e.g., corrective action) have not been explicitly factored into the cost analysis. Therefore, differences between the costs estimated for Subtitle C compliance and those under other scenarios (particularly Subtitle C-Minus) are less than they might be under an alternative set of conditions (e.g., if most affected facilities were not already subject to Subtitle C). The Subtitle C-Minus scenario represents, as discussed above in Chapter 2, the minimum requirements that would apply to any of the special wastes that are ultimately regulated as hazardous wastes; this scenario does not reflect any actual determinations or preliminary judgments concerning the specific requirements that would apply to any such wastes. Further, the Subtitle D-Plus scenario represents one of many possible approaches to a Subtitle D program for special mineral processing wastes, and has been included in this report only for illustrative purposes. The cost estimates provided below for the three scenarios considered in this report must be interpreted accordingly.

In accordance with the spirit of RCRA §8002(p), EPA has focused its analysis on impacts on the firms and facilities generating the special wastes, rather than on net impacts to society in the aggregate. Therefore, the cost analysis has been conducted on an after-tax basis, using a discount rate based on a previously developed estimate of the weighted average cost of capital to U.S. industrial firms (9.49 percent), as discussed in Chapter 2. Waste generation rate estimates (which are directly proportional to costs) for the period of analysis (the present through 1995) have been developed in consultation with the U.S. Bureau of Mines.

In this section, EPA first outlines the way in which it has identified and evaluated the waste management practices that would be employed under different regulatory scenarios by the primary copper facilities generating the three special wastes. Next, the Agency discusses the cost implications of requiring these changes to existing waste management

⁸⁰ Collins, R.J. and R.H. Miller, 1976, op. cit., pp. 150-151, 176, 182.

practices. The last part of this section of the chapter estimates and discusses the ultimate impacts of the increased waste management costs faced by the affected facilities.

6.6.1 Regulatory Scenarios and Required Management Practices

Based upon the information presented above, EPA believes that copper slag and copper calcium sulfate sludge may be EP toxic at some facilities. Accordingly, the Agency has estimated the costs associated with regulation under Subtitle C of RCRA, as well as with two somewhat less stringent regulatory scenarios, referred to here as "Subtitle C-Minus" and "Subtitle D-Plus," as previously introduced in Chapter 2, and as described in specific detail below.

EPA has adopted a conservative approach in conducting its cost analysis for the wastes generated by the primary copper industry. For the two wastes that pose potential risk, the Agency has assumed that these materials would exhibit EP toxicity at all facilities unless actual sampling and analysis data demonstrate otherwise⁸¹. EPA's waste sampling data indicate that copper slag does not exhibit any characteristics of hazardous waste at all but one of the facilities that generate the material. The Agency's cost and impact analysis for slag is therefore limited to that one facility, Phelps Dodge/Playas, whose slag exhibited EP toxicity for cadmium and lead. Similarly, non-confidential sampling data are available from one of the two facilities generating calcium sulfate sludge; these data indicate EP toxicity for arsenic, cadmium, and selenium. Sludge from both facilities is assumed to be potentially hazardous, therefore, cost impacts for both facilities have been estimated. Costs and impacts have not been estimated for copper slag tailings, because the waste does not exhibit any of the four hazardous waste characteristics and appears to pose low overall hazard, as discussed above.

Copper Slag

Subtitle C

Under Subtitle C standards, generators of hazardous waste that is managed on-site must meet the rigorous standards codified at 40 CFR Part 264 for hazardous waste treatment, storage, and disposal facilities. Because copper slag is a solid, non-combustible material, and because under full Subtitle C regulation, hazardous wastes cannot be permanently disposed of in waste piles, EPA has assumed in this analysis that the ultimate disposition of copper slag would be in Subtitle C landfills. Because, however, current practice at the potentially affected primary copper facility is disposal of slag in a wastepile, the Agency has assumed that the facility would also construct a small temporary storage waste pile (with capacity of one week's waste generation) that would enable the operator to send the slag to on-site disposal efficiently. To accommodate the large waste volume generated at the Playas facility (almost 365,000 mt/yr), EPA believes that the least-cost option would be for the facility operator to construct one on-site landfill that meets the minimum technology standards specified at 40 CFR 264, rather than ship the material off-site to a commercial hazardous waste landfill or build multiple landfills. Furthermore, EPA has adopted the conservative assumption that the operator of the smelter would continue to dispose of its slag, rather than attempt to recycle it. The Agency recognizes, however, that given the large quantities of material generated and the high cost of Subtitle C waste management (discussed more fully below), that the affected firm may well choose to recycle, or reduce the generation rates of its smelter slag.

Subtitle C-Minus

A primary difference between full Subtitle C and Subtitle C-minus is the facility-specific application of requirements based on potential risk from the hazardous special waste. Under the C-minus scenario, as well as the Subtitle D-Plus scenario described below, the degree of potential risk of contaminating groundwater resources was used as a decision criterion in determining what level of protection (e.g., liner and closure cap requirements) will be necessary to protect human health and the environment. The Playas facility was determined to have a low potential to contaminate groundwater resources. Therefore, under Subtitle C-minus, the facility would be allowed to continue to operate its

⁸¹An exception to this general approach concerns the anode furnace slag generated at the ASARCO-Amarillo and Phelps Dodge-El Paso facilities, both of which are stand-alone refineries. Because EPA has no sampling data on this specific component of copper slag, and because all anode furnace slag is recycled by all facility operators, the Agency has assumed that generators would not incur compliance costs related to management of this material in the absence of the Mining Waste Exclusion.

present disposal wastepiles, though run-on/run-off and wind dispersal/dust suppression controls are assumed to be required for the unit, as well as groundwater monitoring. In addition, the unit must undergo formal closure, including a cap of crushed stone, and post-closure care must be maintained (e.g., leachate/run-off collection and treatment, cap maintenance, and continued groundwater monitoring) for a period of thirty years.

Subtitle D-Plus

As under both Subtitle C scenarios, the facility operator would, under the Subtitle D-plus scenario, be required to ensure that hazardous contaminants do not escape into the environment. Like the Subtitle C-minus scenario, facility-specific requirements are applied to allow the level of protection to increase as the potential risk to groundwater increases. As the Playas facility has low potential to contaminate groundwater resources, Phelps Dodge is assumed to be allowed to continue operating its disposal wastepile under Subtitle D-Plus. The wastepile would be retrofitted with run-on/run-off and wind dispersal/dust suppression controls which, as with Subtitle C-minus, must be maintained through closure and the post-closure care period. Groundwater monitoring and capping at closure is assumed to not be required for management units under Subtitle D-Plus when the groundwater contamination potential is low, though wind dispersal/dust suppression controls must be maintained.

Calcium Sulfate Wastewater Treatment Plant Sludge

Subtitle C

Under Subtitle C standards, generators of hazardous waste that is managed on-site must meet the rigorous standards codified at 40 CFR Part 264 for hazardous waste treatment, storage, and disposal facilities. Because copper calcium sulfate sludge is a slurry of non-combustible material, EPA has assumed in this analysis that the sludge would be treated and solidified/stabilized in dual Subtitle C treatment surface impoundments, and that the ultimate disposition of the stabilized sludge would be in a Subtitle C landfill. To accommodate the portion disposed, EPA believes that, because of cost considerations, each facility operator would construct two on-site treatment surface impoundments and one on-site landfill that meet the minimum technology standards specified at 40 CFR 264, rather than ship the material off-site to a commercial hazardous waste landfill.

Subtitle C-Minus

A primary difference between full Subtitle C and Subtitle C-minus is the facility-specific application of requirements based on potential risk from the hazardous sludge. Under the C-minus scenario, as well as the Subtitle D-Plus scenario described below, the degree of potential risk of contaminating groundwater resources was used as a decision criterion in determining what level of protection (e.g., liner and closure cap requirements) would be necessary to protect human health and the environment. Both facilities generating potentially hazardous copper calcium sulfate sludge were determined to have a low potential to contaminate groundwater resources. Therefore, under Subtitle C-minus, both facilities would be allowed to continue to operate their present management units. Run-on/run-off controls are assumed to be required for the storage impoundments and disposal units. Groundwater monitoring would be required for both facilities and would continue through closure and the post-closure care period. In addition, the units must undergo formal closure, including a cap of crushed stone underlain by a run-on/leachate collection system to remove the rainfall and snowmelt that would be expected in short but intense surges. Post-closure care must be maintained (e.g., leachate/run-off collection and treatment, cap maintenance, and groundwater monitoring) for a period of thirty years.

In addition to the cost differences between full Subtitle C versus Subtitle C-minus that are attributable to the actual management units, an additional cost difference is associated with the relaxation of the sludge stabilization/solidification requirements. Sludges are assumed to be disposed without stabilization/solidification and the associated costs; in addition, the treatment units (i.e., settling ponds) used to separate sludge and entrained water prior to cementation are no longer required.

Subtitle D-Plus

As under both Subtitle C scenarios, facility operators under the Subtitle D-plus scenario would be required to ensure that hazardous contaminants do not escape into the environment. Like the Subtitle C-Minus scenario, facility-

specific requirements are applied to allow the level of protection to increase as the potential risk to groundwater increases. As the two copper facilities with potentially hazardous copper calcium sulfate sludge both have low potential to contaminate groundwater resources, the facilities are assumed to be allowed to continue operating their disposal units under Subtitle D-Plus. The management units would be retrofitted with run-on/run-off controls which must be maintained through closure and the post-closure care period. Capping the units with crushed stone underlain by a run-on/leachate collection system (i.e., the same as described in the Subtitle C-minus discussion above) is required and must be maintained through the post-closure care period. Groundwater monitoring would not be required for these units because of the low groundwater contamination potential.

In addition to the cost differences between full Subtitle C and Subtitle D-Plus that are attributable to the actual management units, an additional cost difference is associated with the relaxation of the sludge stabilization/solidification requirements. Sludges are assumed to be disposed without stabilization/solidification and its associated costs; in addition, the treatment impoundments (i.e., settling ponds) used to separate sludge and entrained water prior to cementation are no longer required.

6.6.2 Cost Impact Assessment Results

Copper Slag

Results of the cost impact analysis for the Playas smelter are presented for each regulatory scenario in Exhibit

. Under the Subtitle C scenario, Phelps Dodge's annualized regulatory compliance costs are estimated to be just over \$8.6 million more than baseline waste management costs (about 17 times greater). Over \$6.7 million of the increased compliance costs would be for new capital expenditures, or approximately 78 percent of the total.

Under the facility specific risk-related requirements of the Subtitle C-Minus scenario, costs of regulatory compliance are, for the sector, about 82 percent less than the full Subtitle C costs. Phelps Dodge's annualized compliance costs would be \$1.1 million more than the baseline waste management costs (about 3 times greater than baseline). The primary savings over the full Subtitle C costs, due to the consideration of risk potential, are the relaxation of technical requirements and the ability to use disposal wastepiles. New capital expenditures, nearly 95 percent less than under full Subtitle C, would account for about \$362,000 of the incremental C-Minus compliance costs (about 34 percent of the annualized compliance cost).

Regulation under the Subtitle D-Plus program is assumed to require the same management controls as under Subtitle C-Minus, with the exception that, because of the low risk classification, no groundwater monitoring or capping at closure is required under this scenario. Phelps Dodge's annualized regulatory compliance costs would be \$471,000 more than the baseline waste management costs (about 2 times the baseline cost). This represents a decrease of 89 percent from the Subtitle C compliance costs, and a decrease of 38 percent from the Subtitle C-Minus compliance costs.

Copper Calcium Sulfate Sludge

Only two primary copper plants generate calcium sulfate sludge: Kennecott/Garfield, and ASARCO/Hayden. Costs associated with regulatory compliance are shown in Exhibit 6-12

. Both facilities would incur costs under the Subtitle C scenario, with Kennecott/Garfield facing annualized compliance costs of more than \$10.0 million and ASARCO/Hayden almost \$5.2 million. These costs represent increases of almost 10 times current waste management costs. Annualized capital expenditures account for about half of annualized compliance costs, at about \$5.0 million at Kennecott/Garfield and \$2.2 million at ASARCO/Hayden. Other significant contributors to the increase in waste management costs include cement stabilization costs (which are mostly an operating cost) and the costs of operating double lined settling ponds and landfills.

Under the Subtitle C-Minus scenario, annualized compliance costs are estimated at \$1.2 million for Kennecott/Garfield, and \$0.45 million for ASARCO/Hayden (about twice the baseline costs), a decrease for the sector as a whole of 90 percent from the Subtitle C scenario. Relaxation of cementation requirements, and the ability, due to low risk potential, to continue to operate their storage and disposal units with retrofitted controls (e.g., run-on/run-off controls) account for the extremely large cost savings over the full Subtitle C regulatory scenario.

Under the Subtitle D-Plus regulatory scenario, compliance-related waste management costs are 93 percent lower than Subtitle C, for the same reasons that Subtitle C-minus was less costly (e.g., no cementation, no new units required). Costs were nearly 40 percent less than Subtitle C-minus, however, primarily because the requirement for groundwater monitoring is waived for units located in low risk environments under this scenario.

6.6.3 Financial and Economic Impact Assessment

To evaluate the ability of affected facilities to bear these regulatory compliance costs, EPA conducted an impact assessment consisting of three steps. First, the Agency compared the estimated costs to several measures of the financial strength of each facility (in the form of financial impact ratios) to assess the magnitude of the financial burden that would be imposed in the absence of changes in supply, demand, or price. Next, in order to determine whether compliance costs could be distributed to (shared among) other production input and product markets, EPA conducted a qualitative evaluation of the salient market factors that affect the competitive position of domestic copper producers. Finally, the Agency combined the results of the first two steps to arrive at predicted ultimate compliance-related economic impacts on the copper industry. The methods and assumptions used to conduct this analysis are described in Chapter 2 and in Appendices E-3 and E-4 to this document, while detailed results are presented in Appendix E-5.

Financial Ratio Analysis

Copper Slag

EPA believes that Subtitle C regulation might impose significant financial impacts on the Playas facility. As shown in Exhibit 6-13, the annualized incremental costs associated with waste management under Subtitle C represent a significant portion of the value added (more than eight percent) by the Playas smelter. Moreover, the ratio of annualized compliance capital costs to annual sustaining capital investments also suggests a substantial economic impact.

Financial impacts under the Subtitle C-Minus scenario are much less severe than those under the full Subtitle C scenario. The compliance costs as a percent of value added and value of shipments indicate only slight impacts. In addition, compliance capital needs as a percent of sustaining capital are low, at less than 2 percent.

Exhibit 6-13
Significance of Regulatory Compliance Costs for Management of
Copper Slag from Primary Processing^(a)

Facility	CC/VOS	CC/VA	IR/K
Subtitle C			
Phelps Dodge - Playas, NM	2.6%	8.4%	34.1%
Subtitle C-Minus			
Phelps Dodge - Playas, NM	0.3%	1.1%	1.8%
Subtitle D-Plus			
Phelps Dodge - Playas, NM	0.1%	0.5%	0.7%
CC/VOS = Compliance Costs as Percent of Sales CC/VA = Compliance Costs as Percent of Value Added IR/K = Annualized Capital Investment Requirements as Percent of Current Capital Outlays Costs and impacts have been estimated for only those facilities for which sampling data indicate that the waste exhibits a RCRA hazardous waste characteristic. (a) Values reported in this table are based upon EPA's compliance cost estimates. The Agency believes that these values are precise to two significant figures.			

Financial impacts under the Subtitle D-Plus scenario decrease even from the Subtitle C-minus impacts; the Playas facility would not be expected to be substantially affected under this regulatory scenario. The compliance costs as a percent of value added and value of shipments indicate very low impacts to the facility. Compliance capital needs as a percent of sustaining capital are negligible as well, at less than three quarters of one percent.

Calcium Sulfate Wastewater Treatment Plant Sludge

EPA believes that Subtitle C regulation might impose significant financial impacts on the Kennecott and Hayden facilities. As shown in Exhibit 6-14, the annualized incremental costs associated with waste management under Subtitle C represent a significant portion of both the value added and the value of shipments for both facilities generating calcium sulfate sludge. Moreover, the ratio of annualized compliance capital costs to annual sustaining capital investments also suggests potentially significant impacts for these facilities.

Financial impacts under the Subtitle C-Minus scenario are much less severe than full Subtitle C impacts. Compliance costs as a percent of value added and value of shipments indicate only slight impacts at worst (one percent or less). Compliance capital needs as a percent of sustaining capital are also relatively low, at less than 3 percent.

Financial impacts under the Subtitle D-plus scenario decrease even from the Subtitle C-minus impacts; the two facilities are not expected to be significantly affected under this regulatory scenario.

Exhibit 6-14
Significance of Regulatory Compliance Costs for Management of
Calcium Sulfate WWT Plant Sludge from Primary Copper Processing^(a)

Facility	CC/VOS	CC/VA	IR/K
Subtitle C			
Kennecott - Garfield, UT	2.6%	8.4%	21.4%
ASARCO - Hayden, AZ	1.7%	5.4%	12.1%
Subtitle C-Minus			
Kennecott - Garfield, UT	0.3%	1.1%	2.3%
ASARCO - Hayden, AZ	0.1%	0.5%	0.4%
Subtitle D-Plus			
Kennecott - Garfield, UT	0.2%	0.6%	1.7%
ASARCO - Hayden, AZ	0.1%	0.3%	0.3%
CC/VOS = Compliance Costs as Percent of Sales CC/VA = Compliance Costs as Percent of Value Added IR/K = Annualized Capital Investment Requirements as Percent of Current Capital Outlays			
(a) Values reported in this table are based upon EPA's compliance cost estimates. The Agency believes that these values are precise to two significant figures.			

Market Factor Analysis

General Competitive Position

There have been extensive structural changes in the U.S. copper mining and processing industry since the recession of the early 1980s. Coupled with the massive oil industry purchase and divestiture of copper facilities in the late 1970s and mid 1980s, respectively, the present U.S. copper industry looks very different from the U.S. copper industry of a decade ago. The major changes have included:

1. Closure of high-cost mining operations;
2. Modification of mining plans at operating mines that allow for lower cost exploitation of mineral values. Generally this reflects a decrease in stripping ratios or an increase in cut-off grade;
3. Extensive mechanization of mines, including modification of haulage methods;
4. Modernization of milling methods to improve scale economies and recovery;
5. Closure of several high-cost, non-competitive smelters;
6. Improvements in new smelter technology and environmental controls; and,
7. Increases in the production of low-cost solvent extraction-electrowinning (SX-EW) copper.

These technical advances and competitive business decisions were coupled with extensive labor negotiations that checked union wage increases and often rolled back benefits, particularly in the pension area. Along with these labor agreements have been concessions by mines to share the profits and benefits from increased productivity.

Since 1982, when the U.S. provided 17 percent of the world copper mine supply, the domestic copper industry has rebounded to become a major mine producer, currently producing 21 percent of world supply. Substantial increases in the price of copper and the expansion and modernization of the Bingham Canyon (Garfield) mine and smelter complex in Utah have fueled the increase in copper production.

U.S. consumption has returned to the high levels of the late 1970s and early 1980s but still accounts for only about 27 percent of world consumption as opposed to 30 percent in the late 1970s. U.S. facilities (including secondary producers) are again accounting for over 80 percent of domestic requirements.

Potential for Compliance Cost Pass-Through

Labor Markets

Approximately 12,000 workers were employed in the copper sector in 1988, with an average salary of \$28,539. Imposing substantially lower wages to counteract compliance costs is not a likely scenario in the copper processing industry. There have already been significant wage and benefit concessions and movement in the opposite direction with regard to wages is likely over the next few years.

Raw Material Supply Markets

Because recent mergers and property acquisitions in the U.S. industry have resulted in extensive vertical integration, the reduction of prices paid to suppliers is basically an accounting exercise (i.e., shifting expenses from one profit center within a corporation to another). In addition, if copper producers are unable to use the ore that the company generates to produce copper at competitive prices, they can instead sell the concentrate on the world market. In fact, export of concentrate is already occurring; because smelter capacity is less than concentrate production levels, excess U.S. concentrate production is largely exported (approximately 15 percent of domestic mine production was exported in the form of concentrate in 1989).

In the case of suppliers which have concentrate and little smelter capacity, there may be some opportunity to lower prices for their concentrate to compensate for higher compliance costs on the smelter/refinery level. This will depend largely on costs at foreign smelters (including transport of concentrate to the smelters) and whether low costs will allow foreign firms to outbid U.S. smelters for concentrate. If the cost impacts on smelters and refineries are significant, several mines in the U.S. will be able to export their concentrate on favorable terms, though their profit margins will be reduced.

Higher Prices

The copper metal market is a world market and, therefore, U.S. prices must be in line with world prices. The U.S. producers enjoy only a marginal transport cost advantage in supplying U.S. domestic markets, so that significant price increases are not possible. More importantly, only three of the ten domestic facilities that produce refined primary copper would experience increases in waste management costs in the absence of the Mining Waste Exclusion. It is extremely unlikely that these three facilities could successfully pass through compliance costs to domestic consumers (even though in combination they account for more than 40 percent of domestic supply), given the structure of domestic and global copper markets.

Evaluation of Cost/Economic Impacts

All three facilities that generate a potentially hazardous special waste from primary copper processing are expected to incur significant impacts under full Subtitle C regulation; Subtitle C-Minus with its regulatory flexibility, however, would allow for RCRA Subtitle C regulation of these waste with significantly less, and in some cases only marginal, financial impacts. Due to the international nature of the market, and the fact that only one (if only slag is regulated) to three (if both slag and sludge are regulated) facilities would be affected, producers experiencing regulatory impacts would be unlikely to be able to raise prices enough, if at all, to pass through their compliance costs. Consequently, EPA believes that any incremental waste management costs incurred by facilities as a result of a change

in the regulatory status of the special wastes will be borne entirely by these facilities. Nonetheless, because of the regulatory flexibility imparted by RCRA §3004(x), the Agency does not believe that the continued profitability or long-term viability of the affected primary copper facilities would necessarily be threatened by a change in the regulatory status of copper slag or calcium sulfate wastewater treatment plant sludge.

6.7 Summary

As discussed in Chapter 2, EPA developed a step-wise process for considering the information collected in response to the RCRA §8002(p) study factors. This process has enabled the Agency to condense the information presented in the previous six sections of this chapter into three basic categories. For each special waste, these categories address the following three major topics: (1) potential for and documented danger to human health and the environment; (2) the need for and desirability of additional regulation; and (3) the costs and impacts of potential Subtitle C regulation.

Copper Slag

Potential and Documented Danger to Human Health and the Environment

The intrinsic hazard of copper slag is moderate compared to the other mineral processing wastes studied in this report. Data collected by EPA and submitted by industry indicate that most copper slag does not exhibit any of the characteristics of hazardous waste, and hence, would not be subject to Subtitle C regulation if it were to be removed from the Mining Waste Exclusion. However, at one facility (out of seven that were tested), sampling data suggest that copper slag may exhibit the hazardous waste characteristic of EP toxicity -- one sample of the 70 available to EPA for this study contained cadmium and lead in excess of the EP toxicity regulatory levels. None of the slag samples that were analyzed using the SPLP leach test (EPA Method 1312), however, contained constituents in concentrations that exceed the EP toxicity regulatory levels. In addition, copper slag contains seven constituents at levels that exceed the risk screening criteria used in this analysis by a factor of 10. All of these factors lead EPA to conclude that copper slag could pose a moderate risk if mismanaged.

Based on an examination of the characteristics at the 10 active primary copper facilities and predictive modeling, EPA believes that copper slag poses a low risk at most facilities. Almost all of the facilities are located in areas with generally low-risk environmental and exposure characteristics (e.g., very low precipitation and net recharge, large depths to ground water, minimal use of nearby surface and ground-water resources, and great distances to potentially exposed populations). A possible exception is the facility in White Pine, MI. Using the conditions at White Pine as a conservative model, EPA predicts low risks associated with potential dispersal of slag contaminants in ground water and air. Erosion of contaminants into nearby surface waters, however, could cause greater impacts. The Agency predicts that stormwater erosion from a copper slag pile, if not controlled, could result in annual average surface water concentrations of lead, iron, and molybdenum that exceed MCLs or irrigation guidelines, as well as copper concentrations that exceed criteria for the protection of aquatic life. Surface water contamination of this magnitude, however, should not actually occur at the White Pine facility because the slag dump at that facility is equipped with stormwater run-on/run-off controls. Similarly, significant surface water contamination is not expected at the other sites because the nearest surface waters are farther away and have a greater assimilative capacity than that reflected by the conservative conditions that were modeled.

Documented damage cases also show that run-off from copper slag can contaminate surface waters. In some cases, such problems have been eliminated through revised slag management practices, such as collection and treatment of the run-off. At the Commencement Bay Superfund site, however, where slag was used as ballast in a wet, low-lying area, control of the contaminated run-off has been more difficult. Documented cases of damage to ground water at copper smelters was also identified. In all cases, however, the extent to which slag is contributing to the contamination is unclear and there are more probable sources of the observed contamination, such as unlined wastewater impoundments.

Likelihood That Existing Risks/Impacts Will Continue in the Absence of Subtitle C Regulation

At the 10 active copper facilities, the current waste management practices and environmental conditions are expected to limit contaminant migration and exposures in the future in the absence of more stringent Federal regulation. Only one of the active slag piles is lined with a synthetic material (asphalt), only five are equipped with storm water run-on/run-off controls, and dust suppression is practiced at only two of the piles. However, the potential for significant releases to ground and surface water is limited by the extremely arid setting of most sites; in addition, the potential for significant airborne releases is limited by the large particle size of the slag. The primary exception to this generalization is the potential for stormwater erosion into surface water next to the White Pine facility, but the slag pile at this site is equipped with run-off controls that should limit releases through that pathway. Conceivably, exposures could occur at these sites in the future if people moved closer to the waste management units in the future or if ground water very near the units is ever used (assuming that there is useable ground water in the arid settings of most sites). However, considering the relatively moderate intrinsic hazard of this waste, significant exposures at these sites are generally not expected.

There is a potential for the slag to be generated and managed at alternate sites that could be more conducive to releases and risks than the 10 active copper facilities. Several companies have announced plans for expanding existing facilities and building new facilities in entirely new locations (such as Texas City, TX). In addition, there are numerous historical and on-going uses of copper slag at off-site locations, such as use as a highway construction aggregate, a portland cement replacement in concrete, highway embankment material, road or railroad ballast, and as grit in abrasive airblasting. For some off-site uses, such as road sanding, health and environmental concerns have been raised and the use has been discontinued. For other uses, such as airblast abrasive, little if any information on the health and environmental impacts appears to be available. Presumably because most copper slag is generated and used in relatively arid areas of the country, the Commencement Bay log-sort yards are the only known example of damages resulting from off-site use.

The active copper processing facilities that generate slag are located in five states (Texas, Arizona, Utah, Michigan, and New Mexico), all of which adopt the federal hazardous waste regulatory exclusion for mineral processing wastes. The majority of these states do not vigorously regulate mineral processing wastes in general, or copper slag in particular, under their solid waste regulations, even if there are provisions that would allow them to do so. For example, both Utah and New Mexico specifically exempt mineral processing wastes from their solid waste regulations. Moreover, Michigan apparently exempts copper slag generated at the White Pine facility from solid waste regulation because the slag is reprocessed. Although Texas classifies mineral processing wastes as industrial solid wastes, the copper processing facilities currently generating slag are only required to notify the state of their waste management activities. All of the states appear to address some or all of the copper processing wastes to some extent under surface water discharge permitting programs. Both Arizona and New Mexico also have ground-water discharge permit programs, and Utah recently enacted ground-water protection legislation that will require permits. Finally, although all of the states appear to have fugitive dust emission control requirements that could apply to copper slag, the extent to which these requirements are being applied to the slag is not clear.

Costs and Impacts of Subtitle C Regulation

Because of the moderate intrinsic risk potential of this waste and the fact that EPA waste sampling data indicate that copper slag may exhibit the hazardous waste characteristic of EP toxicity, the Agency has evaluated the costs and associated impacts of regulating this waste as a hazardous waste under RCRA Subtitle C. Because, however, data available to EPA indicate that copper slag is not EP toxic at most of the facilities that generate it, the Agency has assumed that this waste would be EP toxic (hence, affected by a change in regulatory status) at only the one facility (Phelps Dodge-Playas) at which a sample indicates exceedances of EP toxicity regulatory levels.

Total costs of regulatory compliance at the Playas copper plant exceed \$8.6 million annually under the full Subtitle C scenario, while under the flexible standards of the Subtitle C-Minus scenario, costs would be 82 percent lower, at just over \$1 million per year. Under the Subtitle D-Plus scenario, annual compliance costs at the Playas facility would be less than \$500,000, a 38 percent reduction from Subtitle C-Minus cost impacts. Full Subtitle C compliance costs represent more than eight percent of the value added by the affected facility, while impacts of the less stringent regulatory scenarios are modest. EPA's economic impact analysis suggests that the operator of the potentially affected facility

would have difficulty passing through any portion of regulatory compliance costs that it might incur to product consumers, because it accounts for less than 15 percent of domestic production and would be the only facility expected to incur regulatory compliance costs if copper slag were to be removed from the Mining Waste Exclusion. Therefore, EPA believes that the operators of the Playas facility would have to bear in full any incremental costs associated with regulation of copper slag under Subtitle C, but that the associated impacts under modified Subtitle C standards would not threaten the continued viability of this facility.

Copper Slag Tailings

Potential and Documented Danger to Human Health and the Environment

The intrinsic hazard of copper slag tailings is relatively low compared to the other mineral processing wastes studied in this report. The tailings do not exhibit any of the four characteristics of hazardous waste, and only 5 constituents were detected in the tailings in concentrations that exceed the conservative risk screening criteria used in this analysis by a factor of 10 or more.

Based on the Agency's review of existing management practices and release/exposure conditions, as well as the lack of documented cases of damage caused by copper slag tailings, the overall hazard associated with management of the tailings appears to be low. Although the tailings are generated as a slurry and co-managed with liquids that could serve as a leaching medium, the concentrations of only three contaminants in the leachate exceed the screening criteria by a factor of 10 or greater. Furthermore, ground water at the three facilities that actively generate and manage the tailings is either very deep (and thus somewhat protected) or currently is not used within a mile downgradient of the waste disposal site. It is possible, however, that ground water close to the slag tailings units could be used sometime in the future. Except for the White Pine facility, where there is a moderate potential for the tailings to migrate to surface water, the potential for the tailings to cause significant surface water contamination appears very remote. Airborne dusting from the tailings piles can and does occasionally occur. Windblown dust from the piles should be studied further and, if necessary, controlled to prevent possible inhalation exposures to arsenic and chromium.

Likelihood That Existing Risks/Impacts Will Continue in the Absence of Subtitle C Regulation

In the absence of more stringent federal regulation, there will continue to be a potential for slag tailings contaminants to migrate into ground water, surface water, and air at some of the active facilities. However, considering the relatively low intrinsic hazard of the tailings, significant exposures at these sites would not be expected unless ground water very near the tailings piles is used or if people moved very close to the piles in the future. The tailings are susceptible to wind erosion when dry, and windblown dust after closure could be a problem, especially in the arid settings of two of the plants. EPA believes that, after closure, measures should be taken to control windblown dust and associated potential inhalation risks to existing and potential future populations.

There is only a slight potential for the tailings to be generated and managed at alternate sites in the future. As discussed above for copper slag, some companies have announced plans to construct new copper processing facilities, but it is uncertain if any of the new facilities would generate slag tailings (not all copper facilities generate slag tailings). Also, given the quantities of tailings involved, it is unlikely that the tailings would be disposed off-site. Slag tailings have been used off-site in the past for highway embankment material and road base, and thus it is conceivable that the tailings could be used off-site again in the future. None of the facilities that currently generate the tailings, however, ship the tailings off-site for use.

The three copper processing facilities that generate slag tailings are located in Arizona, Utah, and Michigan, all of which exclude copper slag tailings from regulation as hazardous waste. In addition, none of these states vigorously regulate mineral processing wastes in general, or copper processing wastes in particular, under their solid waste regulations. For example, Utah specifically exempts mineral processing wastes from its solid waste regulations. Arizona has a ground-water discharge permit program, and Utah recently enacted ground-water protection legislation that will require permits. All three states appear to have general fugitive dust emission control requirements that could apply to copper processing wastes, but the extent to which these requirements are being applied is not clear.

Costs and Impacts of Subtitle C Regulation

Because of the low risk potential of copper slag tailings, the complete absence of documented damages associated with the management of this material, and the fact that this waste does not exhibit any characteristics of hazardous waste, EPA has not estimated the costs and associated impacts of regulating copper slag tailings under RCRA Subtitle C.

Calcium Sulfate Wastewater Treatment Plant Sludge

Potential and Documented Danger to Human Health and the Environment

The intrinsic hazard of calcium sulfate wastewater treatment plant sludge from copper processing is relatively high compared to the other mineral processing wastes studied in this report. Although none of the sludge samples that were analyzed using the SPLP leach test (EPA Method 1312) contained constituents in concentrations above the EP toxicity regulatory levels, several sludge samples analyzed with the EP leach test were found to be EP toxic. Arsenic and selenium were measured in EP leachate in excess of the EP toxicity regulatory level in seven out of seven samples (from the one facility tested). Cadmium was also measured in EP leachate in excess of the EP toxicity level in six out of seven samples. In addition to these exceedances of the EP toxicity regulatory levels, calcium sulfate sludge contains 10 constituents in concentrations that exceed the risk screening criteria used in this analysis by more than a factor of 10. All of these factors lead EPA to conclude that the sludge could pose a significant risk if mismanaged.

Based on a review of existing management practices and facility settings, as well as predictive modeling results, EPA believes that the hazards associated with calcium sulfate sludge are generally low at the two facilities where it is currently generated. Both facilities are located in very arid locations (Hayden, AZ and Garfield, UT) where there is little precipitation and recharge to ground water. Even the liquids used to slurry the sludge into the impoundments are expected to quickly evaporate, rather than seep into the ground. Considering this lack of water to carry sludge contaminants to the subsurface, along with the depths to ground water and the tendency of the sludge contaminants to bind to soil, EPA predicts that it would take more than 200 years for contaminants to migrate from the sludge into ground water. If the impoundment at the Hayden facility is conservatively assumed to be filled with sludge and not equipped with a cover or storm water run-off control system, the Agency predicts that erosion from the impoundment could cause arsenic and silver concentrations in the nearby Gila River that exceed health and ecological protection benchmarks. However, because the impoundment at Hayden is in fact equipped with run-off controls, surface water contamination of this magnitude is not actually expected. The potential for significant releases of windblown dust from the sludge appears very remote, because the surface of the sludge dries to form a crust that is relatively resistant to wind erosion.

No cases of documented damage caused by the sludge were discovered by EPA. This finding supports the conclusion that, as currently managed, the sludge poses a generally low hazard.

Likelihood That Existing Risks/Impacts Will Continue in the Absence of Subtitle C Regulation

Even though the intrinsic hazard of calcium sulfate sludge is high, the risks at the two facilities that currently generate the sludge are expected to remain low in the future in the absence of more stringent federal regulation. This is because the sludge appears to be reasonably well managed at present, and the potential for significant releases and exposures is generally precluded by the environmental conditions at these two sites.

However, there is a potential for the sludge to be generated and managed at alternate sites in the future, especially if the sludge is not regulated under Subtitle C of RCRA. As discussed previously, several companies have announced plans to expand production capacity at existing sites and to construct new copper processing facilities in entirely new locations. Some of these new facilities and locations may be more conducive to releases and risks than the two active sites. Also, although the sludge has not been used or disposed off-site in the past and there are no plans to ship the sludge off-site in the near future, any off-site shipments of the sludge could pose a significant risk if the sludge is not properly managed.

The existing regulatory programs in Arizona and Utah provide only limited controls over the management of calcium sulfate sludge from copper processing. Both states exempt the sludge from hazardous waste regulation, and neither state vigorously regulates the sludge under its solid waste regulations. In fact, Utah specifically exempts mineral processing wastes from its solid waste regulations. Arizona classifies the sludge as solid waste, but to date has not focused its regulatory efforts on the facilities under study. However, Arizona does have a ground-water discharge permit program, and Utah recently enacted ground-water protection legislation that will require permits. In addition, both states appear to have general fugitive dust emission control requirements that could apply to calcium sulfate sludge, but the extent to which these requirements are being applied is not clear.

Cost and Impacts of Subtitle C Regulation

EPA has evaluated the costs and associated impacts of regulating calcium sulfate wastewater treatment plant sludge from primary copper production as a hazardous waste under RCRA Subtitle C. EPA's waste characterization data indicate that this waste exhibits the hazardous waste characteristic of EP toxicity at the one (of two) active facilities for which sampling data were available. EPA has employed the conservative assumption that the calcium sulfate sludge would also be EP toxic at the other (ASARCO-Hayden) facility; the Agency's cost and impact estimates reflect this assumption and therefore may overestimate the impacts of prospective regulation.

Costs of regulatory compliance under the full Subtitle C scenario exceed \$5 million annually at both facilities; these costs would impose potentially significant economic impacts on the operators of the affected plants. Application of the more flexible Subtitle C-Minus regulatory scenario would result in compliance costs that are about 90 percent lower, ranging from about \$450,000 to just under \$1.2 million annually. Costs under the Subtitle D-Plus scenario are approximately 40 percent lower than under Subtitle C-Minus, because of further relaxation of waste management unit design and operating standards.

Subtitle C compliance costs would comprise a significant fraction of the value added by copper smelting/refining operations at both affected facilities; this ratio exceeds eight percent at the Garfield facility and five percent at the Hayden plant. Compliance cost ratios under the Subtitle C-Minus and Subtitle D-Plus scenarios are substantially lower, not exceeding one percent at either facility. EPA's economic impact analysis suggests that the domestic copper industry is currently stronger than it has been in recent years, but would have limited ability to pass through compliance costs in the form of significantly higher prices to product consumers. Moreover, because not all domestic producers would be affected or affected equally (the two potentially affected facilities account for about 30 percent of domestic capacity), it is improbable that the affected facilities would be able to obtain higher product prices in any case. Nonetheless, given the moderate impacts predicted under the flexible management standards of the Subtitle C-Minus scenario, EPA believes that a decision to remove calcium sulfate sludge from the Mining Waste Exclusion would not threaten the long-term profitability and hence, economic viability, of the facilities generating this waste.

Finally, EPA is not aware of any significant recycling or utilization initiatives that would be hampered by a change in the regulatory status of this waste. To date, there have not been any attempts to develop management alternatives to disposal. Impacts on the Agency-wide policy objective of waste minimization are unclear. Calcium sulfate sludge is a pollution control residual that is generated by the treatment of acid plant blowdown and process wastewaters at primary copper smelter/refineries. Because these aqueous waste streams often exhibit characteristics of hazardous waste and have themselves been recently removed from the Mining Waste Exclusion, they will in the future require treatment under RCRA Subtitle C standards. If calcium sulfate sludge were to be regulated as a hazardous waste, facility operators might be more inclined to use treatment methods that generate lesser quantities of more concentrated sludge (e.g., by using caustic instead of lime). In this way, the total quantity of hazardous waste requiring disposal would decrease, though the inherent hazard posed by the treatment sludge would increase. The Agency plans to explore this issue further prior to the Regulatory Determination.

Exhibit 6-11
Compliance Cost Analysis Results for Management of
Copper Slag from Primary Processing^(a)

Facility	Baseline Waste Management Cost	Incremental Costs of Regulatory Compliance								
		Subtitle C			Subtitle C-Minus			Subtitle D-Plus		
	Annual Total (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)
Phelps Dodge - Playas, NM	532	8,611	45,312	6,761	1,077	2,424	362	471	970	145
Total:	532	8,611	45,312	6,761	1,077	2,424	362	471	970	145

(a) Values reported in this table are those computed by EPA's cost estimating model, and are included for illustrative purposes. The data, assumptions, and computational methods underlying these values are such that EPA believes that the compliance cost estimates reported here are precise to two significant figures.

Costs have been estimated only for facilities for which sampling data indicate that the waste would exhibit a RCRA hazardous waste characteristic.

Exhibit 6-12
Compliance Cost Analysis Results for Management of
Calcium Sulfate WWT Plant Sludge from Primary Copper Processing^(a)

Facility	Baseline Waste Management Cost	Incremental Costs of Regulatory Compliance								
		Subtitle C			Subtitle C-Minus			Subtitle D-Plus		
	Annual Total (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)	Annual Total (\$ 000)	Total Capital (\$ 000)	Annual Capital (\$ 000)
Kennecott - Garfield, UT	1,115	9,960	33,225	4,958	1,182	3,589	535	704	2,567	383
Asarco - Hayden, AZ	539	5,187	15,075	2,249	453	512	76	310	370	55
Total:	1,654	15,147	48,300	7,207	1,635	4,100	612	1,014	2,937	438
Average	827	7,574	24,150	3,603	818	2,050	306	507	1,469	219

(a) Values reported in this table are those computed by EPA's cost estimating model, and are included for illustrative purposes. The data, assumptions, and computational methods underlying these values are such that EPA believes that the compliance cost estimates reported here are precise to two significant figures.